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BATTLEFIELD DUST FROM EXPLODING MUNITIONS: CONTRIBUTION BY CRATERING FROM ARTILLERY AND MORTAR PROJECTILES

by

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In this study, a data base was assembled and analyzed on explosion tests of artillery and mortar projectiles and uncased ("bare") charges intended to simulate projectile detonations. The data base represented over 550 tests, mostly in surface and near-surface geometries. Objectives of the study were to find volume-based soil scaling factors (VBSSFs) and crater-ejecta quantities that could be used with existing mathematical dust models, such as the Combined Obscuration Model for Battlefield-Induced Contaminants (COMBIC) to predict battlefield dust.

Crater "shape factors" were developed for both bare charges and munitions to permit calculation of crater volumes based upon linear measurements and thus to enable determination of the VBSSFs. The study showed n to be equal to 0.87 for apparent crater volume and 1.0 for true crater volume. VBSSF values are presented graphically for different soil conditions

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and charge positions. Increased moisture content was found to enhance crater size, whereas dense vegetation inhibited crater formation and ejecta distribution.

Approximately 27 percent of the data base was suitable for calculation of ejecta quantities from sampling measurements or for inference of ejecta quantities by balancing crater volumes. Ratios of ejecta volumes V_e to apparent crater volumes V_a thus obtained were applied to the remainder of the data base to estimate ejecta volumes. A rational method for calculating bare-charge weight necessary to simulate munitions detonations was developed. (SDW)

PREFACE

This study was accomplished in two distinct phases: Phase I established a data base derived from explosion-produced craters associated with munitions common to a modern battlefield, while Phase II provided analysis of this data base. The overall purpose was to provide input to crater-ejecta parameters necessary for assessing battlefield dust in terms of its effect on high-technology sighting, aiming, and tracking systems that will be employed on the battlefield. Results of these phases were published separately; this report combines the two into a single document.

The study was sponsored by Headquarters, US Army Corps of Engineers, and was performed by the Science and Technology Corporation (STC), under the AirLand Battlefield Environment Support Contract No. DACA39-85-C-0006, Project No. 4A162719AT40, Work Unit BO/069, spanning a period of time from August 1985 through December 1986. It was monitored by the Environmental Analysis Group (EAG) of the Environmental Systems Division (ESD), Environmental Laboratory (EL), US Army Engineer Waterways Experiment Station (WES), Vicksburg, MS. During this time, Mr. H. Wade West was Chief, EAG; Ms. Katherine S. Long and Mr. Randall R. Williams, EAG, monitored the study and provided assistance. Dr. Victor R. LaGarde III was Chief, ESD, and Dr. John Harrison was Chief, EL.

The research for both phases was performed and reports were written by Messrs. John N. Strange and Allen D. Rooke, Jr., both of STC-Vicksburg. The initial drafts of these reports were prepared by Ms. Frances R. Charles. The data tables (1-9) were prepared at the Las Cruces, NM, Office of STC by Ms. Thelma Chenault, assisted by Dr. Edward Burlbaw. The report was edited by Ms. Lee T. Byrne of the WES Information Technology Laboratory.

COL Dwayne G. Lee, EN, was the Commander and Director of WES. Dr. Robert W. Whalin was Technical Director.

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CONVERSION FACTORS, NON-SI TO SI (METRIC) UNITS OF MEASUREMENT

Non-SI units of measurement used in this report can be converted to SI (metric) units as follows:

Multiply	By	To Obtain
degrees (angle)	0.01745329	radians
inches	2.54	centimetres
pounds (force)	4.448222	newtons
pounds (mass)	0.4535924	kilograms
tons (force)	8.896444	kilonewtons

BATTLEFIELD DUST FROM EXPLODING MUNITIONS: CONTRIBUTION BY CRATERING FROM ARTILLERY AND MORTAR PROJECTILES

PART I: INTRODUCTION

Background

1. The problem of dust loading in the near-surface atmosphere as it affects the modern battlefield environment was clearly established during the North African campaigns of World War II. Both men and machines were severely affected by it--men, by respiration and eye irritations and infections, and machines, by engine and abrasion problems that caused high failure rates and compounded the difficult logistics in that theater.

2. Since that time, the level of technology on the battlefield has increased markedly, and dust-laden air space has become an even greater factor in military operations, as demonstrated in the recent Middle East wars. High-technology tracking and aiming devices may not function properly during periods when critical dust-cloud concentrations are present. Whether the dust stems from natural causes, such as a dust storm (or "haboob"), or from a variety of battlefield activities, such as moving vehicles and exploding munitions, the problem is the same when dust concentrations reach critical levels.

3. Dust loading resulting from military operations common to the battlefield varies widely, depending upon geographic location (i.e., soil composition), climate, season, and to some extent, even the time of day. Research by the US Army Engineer Waterways Experiment Station (WES), Vicksburg, MS, is aimed at developing realistic methods for predicting dust loadings resulting from military activities in desert terrain, especially in those areas where conventional military operations appear most likely. As input to a prediction methodology for determining dust concentrations within dust clouds generated by exploding munitions, Science and Technology Corporation, under contract to WES, compiled a data base documenting crater size and shape and ejecta volume from explosions representative of the range of energy yields common to such munitions. The surveyed explosions involved bare (uncased) high-explosive (HE) charges as well as static and live-fired munitions in a variety of soils. This field study was followed by an analysis

of the data base, which established volume-based soil scaling factors (VBSSFs)* suitable for mathematical modeling algorithms, as well as other cratering relations. This report combines the findings of the preceding research efforts.

Purposes and Scopes

4. The purposes of this study are: (a) to publish a comprehensive data base that can be used to quantify VBSSFs as they vary with soil type and, to the degree possible, to assess the effect of vegetative cover on the VBSSFs and on the crater-ejection process for near-surface charges in the weight range of roughly 1 to 120 kg** (which includes the range of explosive weights common to most conventional munitions expected on the modern battlefield) and (b) to perform a detailed empirical analysis of the acquired data base to quantify the VBSSFs and crater-ejecta parameters for the soils and shot geometries included.

5. The third and final phase of this research (Phase III) will, if authorized, review and hopefully improve the numerical input to various dust codes, e.g., the Combined Obscuration Model for Battlefield-Induced Contaminants (COMBIC) using the findings of this study.

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* Crater volume divided by charge weight raised to some exponential value.

** Strictly speaking, the kilogram (1 kg = 2.205 lb, mass) is a unit of mass, not weight. It is used here as a unit of force (weight) in the Earth's gravitational field, i.e., 1 kg = 2.205 lb, force, in place of the correct but unfamiliar newton (1 N = 0.225 lb, force). Actually the 120-kg weight limit stated above represents 265 lb or 1,177 N.

PART II: COMPILATION PROCEDURES

Literature Survey

6. Resources consulted and documented in the accomplishment of this study are listed in the References at the end of the main text. This listing, which is alphabetical by principal author (or organization), includes material that furnished direct input to this study. Other material used for general background information but not cited in the text are listed in the Bibliography.

Data Tabulation Formatting

7. Narrative descriptions of most of the test sites from which data for this study were used are provided in Part III. The results of the literature search are discussed in Part IV, and the nine data tables found at the end of the report contain VBSSFs for all explosion-crater events considered as well as the results of crater-ejecta measurements, calculations, and estimates. The events recorded in these tables are mostly uncased charges, but Tables 5 and 9 include data from static and live projectile firings. Finally, there are five "nondata" tables, four of which document the development of study parameters used in connection with the projectile craters and one of which records the development of crater-ejecta relations for uncased charges.

8. Upon completion, the data base matrix of Tables 1-9 (row by column) was 516 by 35; each row is identified by a unique number for ease of reference. The data tables are contained in both the Phase I* and Phase II** reports, as well as here, with final additions and corrections being included in the Phase II report and here. However, there are a number of incomplete entries, limited by the measurements that could be found or reasonably inferred.

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* Allen D. Rooke, Jr., and John N. Strange. 1986. "Battlefield Dust from Exploding Munitions: A Data Base Descriptive of the Contribution by Cratering," STC Technical Report 2096, Science and Technology Corporation, Hampton, VA.

** John N. Strange, and Allen D. Rooke, Jr. 1986. "Battlefield Dust from Exploding Munitions: An Analysis of the Phase I Data Base," STC Technical Report 2123, Science and Technology Corporation, Hampton, VA.

PART III: SOIL DESCRIPTIONS OF THE VARIOUS TEST AREAS

9. One of the major objectives of this study was to develop VBSSFs that could be correlated directly to specific soil types, such as those specified by the Unified Soil Classification System (USCS). Unfortunately, it was found during the course of the literature search that only in the more recent studies of cratering had soil descriptions for various test sites been sufficiently examined/tested to state a USCS designation. Where such designations were made, obviously they were used. Where designations were not made within the body of a given report, the authors of this report have estimated USCS designations based on word descriptions of the natural soils present at the various sites and, in some cases, on personal knowledge of soil conditions at various sites. Estimated USCS designations have been clearly identified as such.

10. For the purpose of this study, where so many site descriptions are nonspecific, a triangular classification chart (Figure 1), similar to that of the US Department of Agriculture (USDA), has been prepared to give a quantitative indication of the proportion of sand, silt, and clay present in the natural soils. Note that the soil types identified in Figure 1 are uniquely related to the word descriptions given for the various sites.

11. In addition, a delineation of soil type relative to particle size is given below:

Material	Particle Size (PS), mm
Clay	$PS \le 0.005$
Silt	$0.005 < PS \le 0.07$
Sand (fine)	$0.07 < PS \le 0.20$
(medium)	$0.20 < PS \le 0.6$
(coarse)	$0.6 < PS \le 2$
Gravel (fine)	$2 < PS \le 10$
(coarse)	$10 < PS \le 70$
Boulders	$PS \ge 70$

These particle-size statistics are based on a concensus evaluation of a number of different size groupings from different organizations, specifically, the American Society for Testing and Materials, the Federal Aviation Administration, the USCS, The American Association of State Highway Officials, the USDA, and the Massachusetts Institute of Technology.

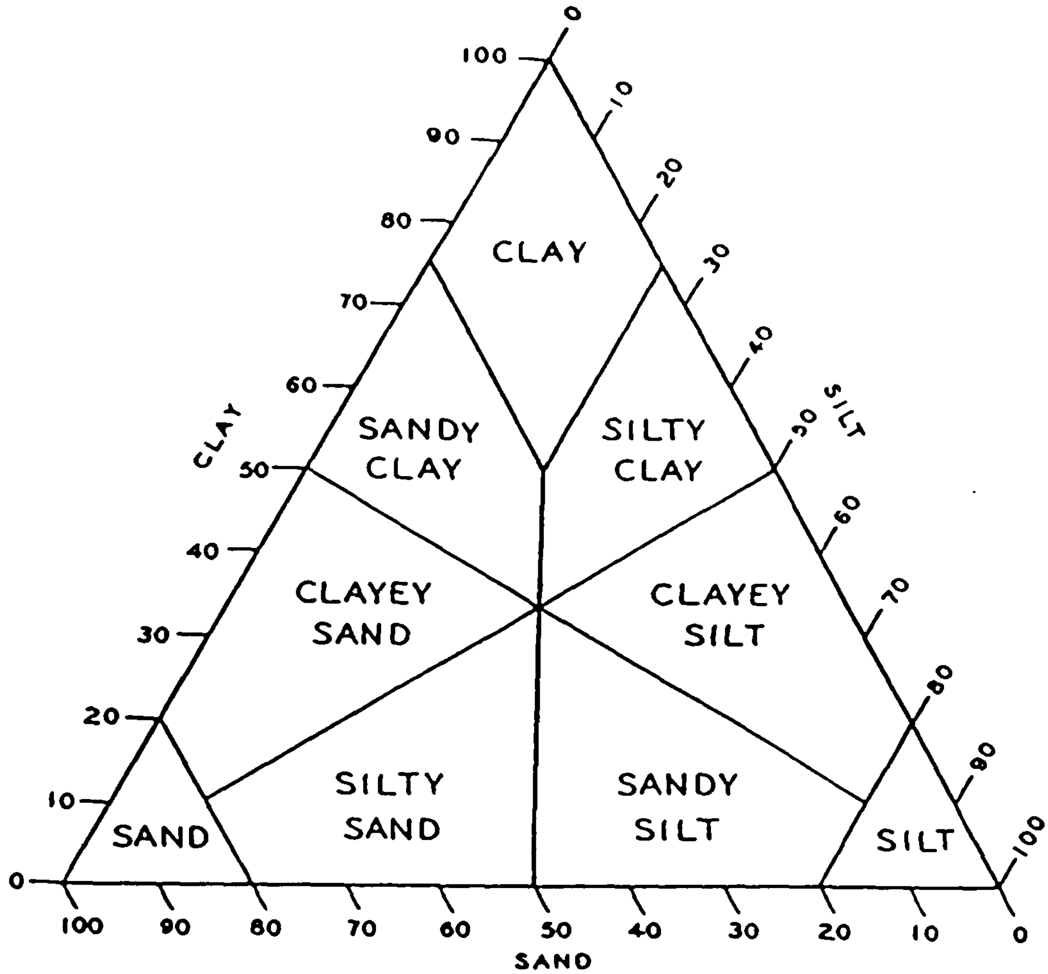


Figure 1. Soil classification chart

12. The word descriptions of the soils at the various sites, with their stated or estimated USCS designations, are presented in the following paragraphs, along with references. Where soil descriptions or even test site locations were nonspecific, the authors have substituted their best judgments. Descriptions of vegetative cover are also included where applicable and/or available. In most cases where there is no description of vegetative cover, the reader may assume that testing was done on bare ground or that vegetation was so sparse that it could be ignored. However, descriptions for the following sites were not available: Fort Benning (paragraph 21), Panama Canal (paragraph 37), and miscellaneous sites (paragraph 41).

Big Black Test Site (BBTS)

Cratering effects of surface and buried HE charges in loess and clay

13. The BBTS is a WES test site, located about 12 miles east-southeast of Vicksburg, Miss. The loess test pad at this site had an average moisture content of 19 percent during the test period. Other properties were: average density of 1,640 kg/m^3 (~102 lb/ft^3), liquid limit of 44.8, a plastic limit of 24.3, and a plasticity index of 20.5. The USCS designation was estimated as CL, and the percent sand/silt/clay/moisture content/degree of saturation (SSCMS) is estimated as 10e/40e/50e/10e/20e (the lower-case "e" is used here to indicate estimated quantities).

14. The clay test pad had an average moisture content of 21 percent during the test period. Other mechanical properties were: average density of 1,874 kg/m^3 (~117 lb/ft^3), liquid limit of 43, a plastic limit of 23, and a plasticity index of 20. The estimated USCS designation was CL-CH; the SSCMS is 5e/20e/75e/10e/25e (WES 1958a).

Craters formed by small explosions in dry sand

15. The test bed for the series was a dry (moisture content less than 6 percent), well-graded sand. The USCS designation was SW; the SSCMS is 100e/0e/0e/<6/10e (Sager 1962).

Effects of a soil-rock interface on cratering

16. These tests were conducted in a uniformly graded sand overlying a massive concrete block of sufficient thickness to act as solid rock for the scale of the experiment. Only those cratering data from sand-layer thicknesses of sufficient depth to negate the effects of the underlying concrete block are used here.

17. Moisture contents within the sand layer ranged from 4.4 percent near the surface to 7.5 percent at the sand-concrete interface; it was classified as dry-to-moist, with an estimated USCS designation of SP. The SSCMS is 100e/0e/0e/4e to 8/15e. For the wet-sand tests, the moisture content was 12 to 15 percent with saturation of about 20 percent (WES 1958b).

The influence of a
shallow water table on cratering

18. A special test bed of uniform washed masonry sand was used for these tests. Only the data from shots where the water table was sufficiently deep so as not to affect crater formation are used here. The USCS designation was SP, with an SSCMS of 100/0/0/15e/25e (Carnes 1981).

Eglin Air Force Base

19. Two separate series of explosion tests, SMOKE WEEK II and SMOKE WEEK III, were conducted at Test Range C5A in the eastern part of Eglin Air Force Base. The soil at this site was classified as a more or less uniform sand with minor amounts of silt and clay. The USCS designation was estimated to be SP, while the SSCMS designation is 80e/10e/10e/<9/20e. The moisture content at depths of 3 to 10 cm averaged in the range of 5 to 7 percent.

20. Vegetation consisting of grasses, herbs, and forbs covered about 50 percent of the area. Vegetation was removed from shot sites for SMOKE WEEK II, but was not removed for SMOKE WEEK III (Mason and Long 1983a).

Fort Benning, GA

21. The Portable Bunker Tests were conducted on the Coolidge Mortar Range and the Spafford Artillery Range at Fort Benning. The soil at both ranges was a moist silty sand with a USCS designation of SM. On the mortar range, a clayey sand (USCS designation SC) was found at a depth of 0.6; however, this horizon was penetrated only once by the explosion trials. The SSCMS designation is 60e/30e/10e/5e/7e (Hoot 1971).

Fort Carson, CO

22. The surface soil at Site 1 of the Dust Obscuration Test Series I (DOT I) was a sandy clay material, light brown in color. The USCS designation was a sandy clay (CL). Near-surface moisture contents taken in the upper 10 to 15 cm ranged from 6.7 to 26.7 percent, the higher value occurring soon after a light rain. Cone index readings (a measure of the bearing capacity of soils relating mainly to trafficability) at depth were: 50 at surface, 200 at

15 cm, and 750+ at 30 cm. The SSCMS designation is 35e/10e/55e/7 to 25/20e to 50e.

23. At Site 2 (DOT II) the soil was a sandy clay, sandy silt classified as CL. At the time of the testing, the moisture content ranged from 7.2 to 17.5 percent, the higher value again occurring soon after a light rain. Cone index readings at depth were: 100 at the surface and 750+ at 15 to 30 cm. For Site 2, the SSCMS designation is 30e/35e/35e/7 to 17.5/15e to 30e.

24. Some ground cover was present: "short grasses, blue grama, Russian thistle, lamb's quarters, and prickly pear." Ground coverage was 50 to 70 percent on the average; plant height generally ranged from 10 to 20 cm (Long, Mason, and Durst 1984; Long and Williams 1985; Long et al. 1985).

Fort Polk, LA

Munitions/bare charge equivalence Series II (MBCE II)

25. These experiments were conducted within the confines of Range 37 at Fort Polk, as were the Battlefield Environments in Tailored Soils (BETS) tests. The soils to a depth of 2 m consisted of 0.3 m of tan sandy clay overlying about 1 m of tan to reddish-tan plastic clay, which in turn overlay reddish-tan to brown clay. The dominant soil type, within the depths affected by the various shots, was classed as a sandy clay (estimated USCS, CL), with an SSCMS of about 30e/10e/60e/10 to 30 (average ~20)/20e to 60e (average 40e) (Mason and Long 1983b).

BETS

26. The BETS tests were conducted at a time when the average moisture content was lower than on the MBCE program, or about 10 percent. Especially prepared test beds were used for these tests. They were: (a) inorganic clay (CH); (b) mixture of inorganic silts, some clay, and some fine sand (ML); (c) poorly graded sand (SP); (d) inorganic clay-sand mixture (CH/SP); (e) silty sand (ML-SP); and (f) kaolin (CH).

27. The organic content of the Range 37 soils varied from 1+ to nearly 7 percent, with an average of about 3.5 percent (Mason and Long 1983b).

Mono Lake, CA

28. A number of cratering experiments were conducted on the south shore of Mono Lake, where the soil was pumice sand, with only minor amounts of silt and clay. The sand was uniform in size, with grain size in the main a millimetre or less in diameter. The USCS designation was SP, with an estimated SSCMS of 90e/5e/5e/varies/varies (Davis 1967).

Tropic Test Center (TTC), Isthmus of Panama

29. Explosion tests were conducted at three sites in TTC under the Battlefield Obscuration in the Tropics test program. At TTC Empire Range 6 on the Pacific side of the Isthmus, the dominant soil was a moist silty clay with a liquid limit that ranged from 50 to 60. The USCS designation was nearly always MH; the SSCMS averages about 24e/55e/21e/35e/70e.

30. The Mindi Farm test area is on the Atlantic side of the Isthmus; the soil there was primarily silt with some fine sand and a trace of clay. This material was moist-to-wet (but generally more wet than moist); moisture contents ranged from 70 percent at the surface to 40 percent at a depth equal to crater depth. The USCS designation was MH, with an estimated SSCMS that averages about 38e/57e/5e/60/85e.

31. At the Mindi Farm site, charges were detonated in three different levels of vegetation: bare soil cleared of all vegetation, *Gynerium sagittatum* 0.3 to 0.5 m high, and the same vegetation 3 to 4 m high.

32. The Piña Beach site is located on the Atlantic side of the Isthmus, approximately 1 km southwest of the mouth of the Chagres River. The beach material was fine coastal sands with traces of silt and gravel. Charges were detonated in three soils and three types of vegetation. The soils were "white saturated sand (shoreline); white, wet (top centimetre partially dry) sand; black, wet (top centimetre partially dry) sand; the types of vegetation were *Ipomoea pes-caprae* (morning glory), *Hymenocallis americana* (spider lily), and *Panicum maximum* (2 to 3 m high." The average SSCMS for Piña Beach is estimated as 93e/7e/0/10e/20e (Martinucci and Fuchs 1981).

White Sands Missile Range (WSMR)

Dusty Infrared Test (DIRT) Series I and II

33. The DIRT I tests were conducted in the Orogrande (southeast) area of WSMR. The near-surface soils in the area were composed principally of dry-to-moist brown silty sand. The estimated USCS was classified as SM; the SSCMS is taken as 60e/35e/5e/3 to 13/20e.

34. The DIRT II series was conducted in the Queen 15 area in north-central WSMR. The material was an alluvial deposit described as a moist silty clay, estimated to be CL-ML, with silt and some sand. The water table lay at a depth of about 2 m. The SSCMS is 15e/35e/50e/10 (near the surface; at 1-m depth the moisture content was 24 percent, for an overall average 10 to 15e)/20e to 40e (average = 30e).

Battlefield Induced Contaminants (BICT) Series III

35. This series was conducted in the Orogrande area, WSMR, described in paragraph 33.

Munitions/bare charge equivalence Series I

36. Series I of MBCE was held in the Queen 15 area of WSMR, described in paragraph 34. (MBCE II is discussed in paragraph 25.) (See Joachim and Davis (1983); Rooke (1983); Williams and Lebron (in preparation)).

Miscellaneous Sites

Panama Canal studies

37. The Panama Canal tests were conducted in residual clay estimated to be OL (wet) and in marine muck estimated to be OH, near saturation. Moisture contents in both materials were in excess of 40 percent. Specific weights for the residual clay were: 1,767 kg/m^3 (wet) and 1,169 kg/m^3 (dry); the SSCMS is 5e/20e/75e/40 to 50e/70e to 80e (US Special Engineering Division, The Panama Canal 1948a and 1948b).

Small explosion
tests--Project MOLE

38. These experiments were conducted in four rather basic soil types: dry clay (Utah), sand with some gravel (Nevada Test Site), wet sand (California), and moist clay (California). The USCS classifications were estimated as follows (Sachs and Swift 1955):

Word Description	Estimated USCS Designation
Dry clay	CL
Sand with some gravel	GM
Wet sand	SW
Moist clay	CL

Suffield Experimental
Station (SES), Alberta, Canada

39. The Distant Plain Series was conducted within the confines of the Watching Hill and Drowning Ford Test Ranges, SES, where the general topography was that of a gently rolling plain sparsely vegetated by buffalo and spear grasses. The soil at the Watching Hill site was a glacial deposit with strata as defined by the following tabulation:

Word Description	Estimated USCS Designation	Depth, m
Silty clay	OL	0 - 1.5
Lean clay, sandy or silty	SM	1.5 - 9
Clay	CL	9 - 25
Coarse sand and gravel	GP	25 - ?

The SSCMS is 10e/25e/65e/10e/15e through the 0- to 3-m horizon (Jones, Spackman, and Winfield 1959; Jones et al. 1970).

40. The origin of the soils at the Drowning Ford test area was also a glacial deposit, with the underlying strata described as follows:

Word Description	Estimated USCS Designation	Depth, m
Clayey silt	ML	0 - 3.5
Sandy silt	SM	3.5 - 4.0
Sand/gravel mix	SW	4.0 - 13.5
Clayey silt	ML	3.5 - ?

For the Drowning Ford site, the SSCMS as a rough average is 10e/55e/35e/10e/15e within the 0- to 3-m horizon (Jones, Spackman, and Winfield 1959; Jones et al. 1970).

Effects of underground explosions

41. These tests were conducted at three sites: Princeton, N. J.; Clear Lake, Tex.; and Natchez, Miss. The estimated USCS designations for the three sites were as follows: Princeton--MH, underlain at shallow depth by CL; Clear Lake--CL; and Natchez--CL. There are insufficient data available on these tests, conducted in the 1950s, to permit an estimate of SSCMS (Engineering Research Associates 1952).

Underground explosion test program

42. Tests were conducted in rather commonly occurring soil types, namely, dry clay (estimated as CL), dry sand (estimated as SP-SM dry), and wet clay (estimated as CL). Here again, no SSCMS can be estimated (Engineering Research Associates 1952).

Operation Prairie Flat

43. This test was conducted at SES Watching Hill Range, described in paragraph 39 (Jones, Spackman, and Winfield 1959; Jones et al. 1970).

PART IV: ANALYSIS

Purposes

44. The main efforts in the analysis of the compiled data are to document in a quantitative fashion the VBSSFs, the scaling law relating crater volume and the quantity of explosive (charge weight), and to develop means of estimating ejecta volume as a fraction of crater volume. In so doing, differences between cased and uncased charges have been noted. The analysis of the compiled data is reflected in the remaining portions of this report.

Determination of Crater Volume: Crater Shape Factors

Apparent craters

45. Figure 2 is an idealized profile of a crater formed by a near-surface explosion. If one assumes that the apparent crater volume is directly proportional to a variation of the square of the crater radius times the crater depth, then it is possible to develop a crater shape factor in order to calculate crater volume from the measures of radius and depth. The simplest way to arrive at such a factor is to compare the actual apparent crater volume with that of a fictitious right circular cylinder having the same radius and height (in this case depth) as the crater, i.e., compare the apparent crater volume V_a with $\pi r_a^2 d_a$, where r_a is the apparent crater radius and d_a is the apparent crater depth.

46. If V_a is assumed to be directly proportional to $\pi r_a^2 d_a$, an assumption borne out by experimental results, then

$$V_a = C_a(\pi r_a^2 d_a) \tag{1}$$

and for the true crater, denoted by the subscript t,

$$V_t = C_t(\pi r_t^2 d_t) \tag{2}$$

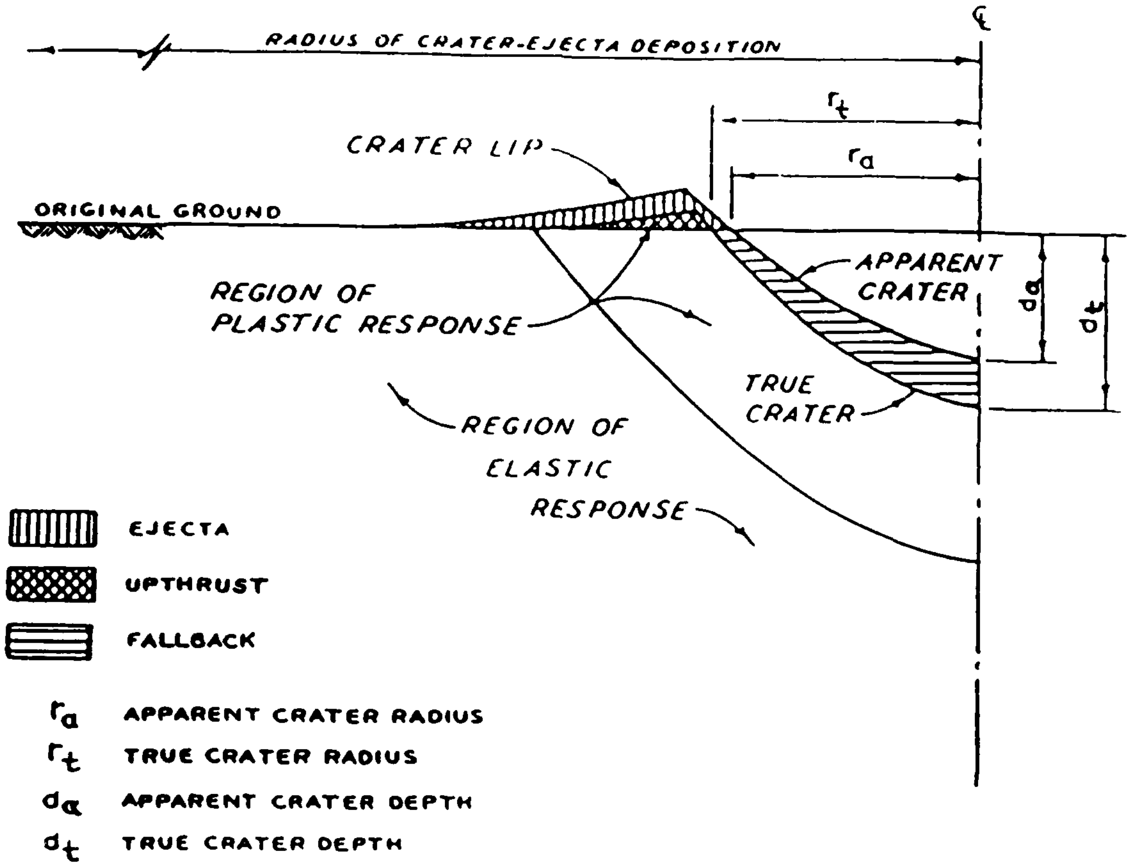


Figure 2. Idealized half-crater profiles

By definition, the C terms become the crater shape factors K_s used in Tables 1-9 for both apparent and true craters. In the tables, apparent and true shape factors are separated by a slash, apparent/true. In the text discussion, they will be shown as $(K_s)_a$ and $(K_s)_t$.

47. The data from fully reported, bare-charge cratering events in various soils from various heights (depths) of burst, and with charge weights ranging from 0.5 kg to as much as 500,000 kg (TNT equivalent), resulted in a $(K_s)_a$ that averaged 0.45 with a standard deviation of σ of only 0.07. The range of $(K_s)_a$ values was from 0.28 to 0.59. With $(K_s)_a = 0.45$, the crater shape more nearly approximates a paraboloid ($K_s = 1/2$) as opposed to a cone ($K_s = 1/3$) or a hyperboloid ($K_s = 2/3$). Even though the crater aspect ratio

(r_a/d_a) for the data base developed varied from 1.5 to 10, the crater shape factor varied only from 0.28 to 0.59, with the mean value being 0.45.

48. With the crater shape factor known, it is possible to calculate the apparent crater volume from the measured crater depth and radius. With $(K_s)_a = 0.45$, the apparent crater volume is given by

$$V_a = (K_s)_a \pi r_a^2 d_a = 0.45 \left(\pi r_a^2 d_a\right) \tag{3}$$

or

$$V_a = 1.41\ r_a^2 d_a$$

Thus for bare-charge apparent craters, a shape factor of 0.45 should be used in calculating crater volume from measured values of radius and depth for the range of charge positions considered, which may be expressed in terms of an equivalent spherical TNT charge with radius R_c, where $-2.5 \le R_c \le 4.0$.

<u>True craters</u>

49. A similar treatment of true crater results shows $(K_s)_t$ to have a value of 0.40, indicating a tendency to be a bit more conical in shape than the apparent crater. A typical true crater shape is shown in Figure 2 along with the apparent crater and the elastic- and plastic-response zones. The compression/compaction cavity (the bottom portion of the true crater profile) is obviously paraboloidal, while the side walls (upper portion of the true crater profile) form a truncated cone, thus making the overall shape of the true crater a combination of the two, i.e., a cone ($K_s = 1/3$) and a paraboloid ($K_s = 1/2$).

50. With $(K_s)_t = 0.40$, and knowing the true crater radius (r_t) and depth (d_t), it is possible to calculate the true crater volume (V_t) from

$$V_t = (K_s)_t \left(\pi r_t^2 d_t\right) = 0.40 \left(\pi r_t^2 d_t\right) \tag{4}$$

or

$$V_t = 1.26\ r_t^2 d_t$$

Thus, for true craters, a shape factor of 0.40 should be used to calculate true crater volume from measured values of radius and depth, again within the range of charge positions considered ($-2.5 \leq R_c \leq 4.0$).

Crater shape factors, munitions

51. Implicit in this study is a requirement to compare the limited data base available for exploding munitions with that for bare charges. The purpose, of course, is to answer the question: How well do craters formed by bare charges simulate those formed by commonly used battlefield munitions, such as artillery and mortar projectiles? Bare charges are safer and more convenient than munitions for conducting battlefield cratering (and ejecta/dust-lofting) experiments, but only insofar as they satisfactorily represent the cratering effects of munitions.

52. A typical live-fire apparent crater profile for an artillery projectile launched by cannon is shown in Figure 3. Craters from live-fire munitions differ little from static-fire craters, where shells are manually emplaced, even though in the live-fire case, shell fragments possess a forward velocity vector equal to the shell's velocity vector. Shell craters are

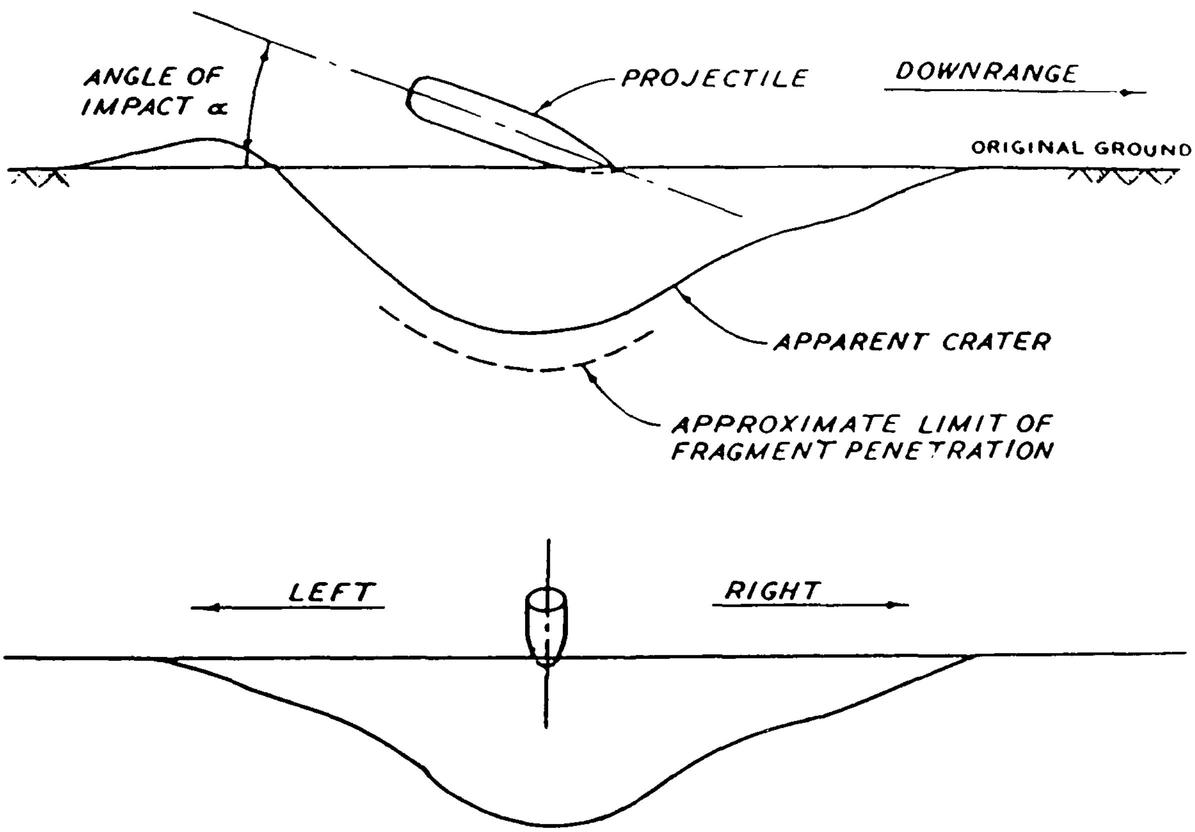


Figure 3. Typical live-fire HE projectile crater

typically asymmetric, with the uprange radius generally less than the downrange radius; both of these differ from the lateral (cross-range) radii, which are generally the same.

53. Figure 4 shows apparent crater shape factors for munitions. In spite of the asymmetry of munition craters compared with the usually symmetrical bare-charge craters, the shape factors for munition craters range from 0.22 to 0.78 as read from the abscissa values, excluding the seemingly anomalous point P ; this gives an average value of $K_s = 0.46$. Thus, in the

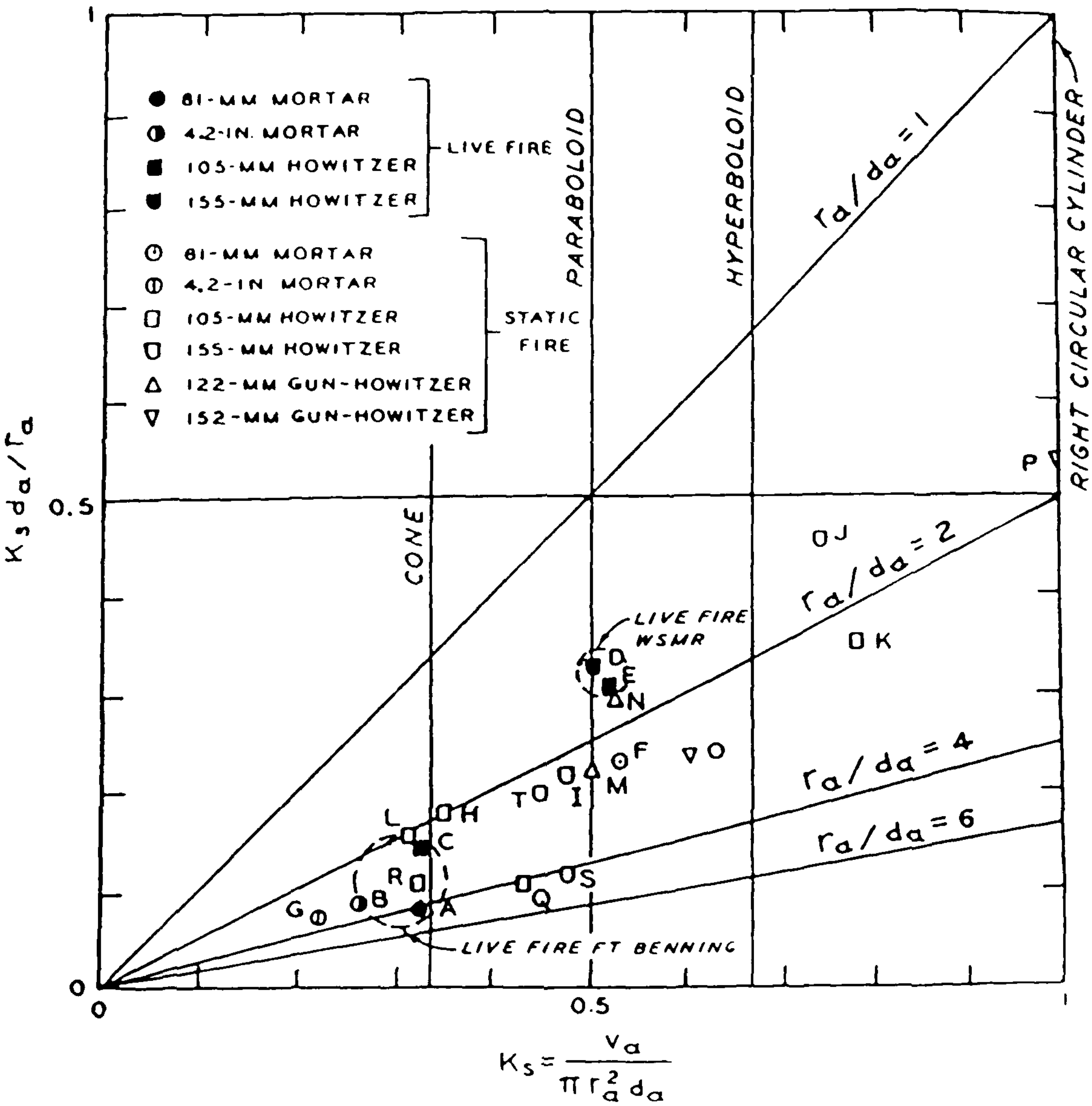


Figure 4. Shape factors K_s for HE projectile craters. (Data points are described in Table 10)

absence of a uniquely defined munition shape factor, the average radius and measured depth may be used in conjunction with the appropriate bare-charge shape factor (0.45 for apparent and 0.40 for true) to calculate crater volume.

VBSSFs

Apparent craters: unrestricted analysis

54. Dimensional analysis considerations dictate that crater volume, both apparent and true, should vary directly as charge weight, i.e., a doubling of charge weight should result in the doubling of the crater volume for similarly scaled charge positions and similar soils. Thompson and DeVore (1982), using cratering data from a number of sources, found that, for charge yields appropriate to their study, the apparent crater volume varied as the charge weight to the 1.111 power, i.e.,

$$V_a \propto W^{1.111} \tag{5}$$

where W is charge weight.

55. To test the validity of Equation 5 to the data base compiled during the Phase I portion of this study, a plot was made in which restricted ($W < 1{,}000$ kg) and unrestricted ($W < 1{,}000{,}000$ kg) graphs were drawn (Figure 5). The plot is an all-data plot, meaning that data from all different soil types and all charge positions were included. The plot exhibits a vertical scatter of roughly two orders of magnitude, implying that the extremes of soil types (from wet clay to rock) and the extremes of charge position ($-2.3 \le R_c \le 4$) are capable of producing only a two-order-of-magnitude scatter in apparent crater volume for a given charge weight. Thus, the effect of wide variations in soil types as well as variations in charge position in the near-surface regime may be expected to produce little more than a two-order-of-magnitude scatter in plots of apparent crater volume versus charge weight over a wide range of yields.

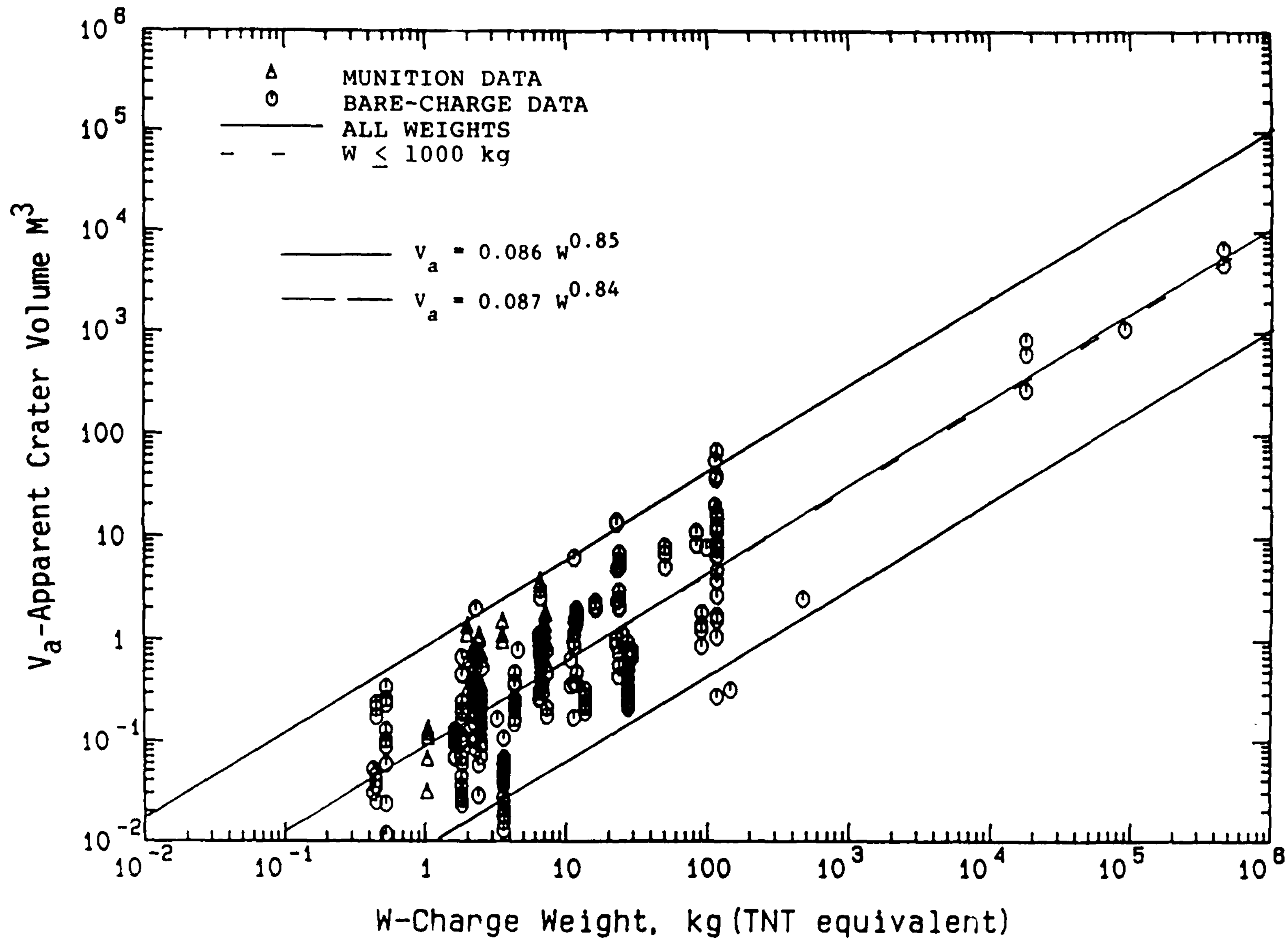


Figure 5. Variation of apparent crater volume with charge weight (all soil types, all charge positions). Graph contains 478 data points

56. The graph of Figure 5, in which approximately 95 percent of the 478 data points fall within the scatter band shown, provides a massive array of points for slope determination. A least squares fit of the data suggests that

$$V_a \propto W^{0.85} \tag{6}$$

When charge yields are restricted such that $W \leq 1{,}000$ kg , the variation of apparent crater volume with charge weight follows the proportional equation

$$V_a \propto W^{0.84} \tag{7}$$

In both Equations 6 and 7, the exponent is, for all practical purposes, the same and is substantially below the 1.111 variation reported by Thompson and DeVore (1982) from their less extensive data base.

57. Comparison of Equations 6 and 7 convincingly shows that even to the million-kilogram yield level the same scaling laws are applicable as when charge weights are restricted to the thousand-kilogram level. This similarity indicates that there is no significant change in cratering phenomena or in energy partitioning phenomena over a seven-order-of-magnitude change in charge yield.

58. Figures 6 and 7 present plots of apparent crater volume as a function of charge weight for $0 \leq R_c \leq 1$ and $-1.0 \leq R_c \leq 0$, respectively. The plots show slopes (exponents of W) of 0.84 and 0.90 when $W < 1{,}000{,}000$ kg and 0.78 and 0.89 when $W \leq 1{,}000$ kg. Again, the vertical scatter is roughly two orders of magnitude for both plots.

59. It appears at this point, by virtue of the preponderance of data shown in Figures 5-7, that the 1.111 exponent previously assumed is too high. These data tend to support an exponent in the range of 0.85 to 0.90 for charge weights less than 1,000,000 kg.

60. It must be emphasized at this point that the exponents derived from Figures 5-7 are for correlations where all soil types and all charge positions or ranges of charge positions are lumped together to provide the respective plots. This lumping of data presumes that each soil type and each restricted range of charge position, as an overall average, will follow the same scaling laws and that the plots for more restrictive correlations will be described

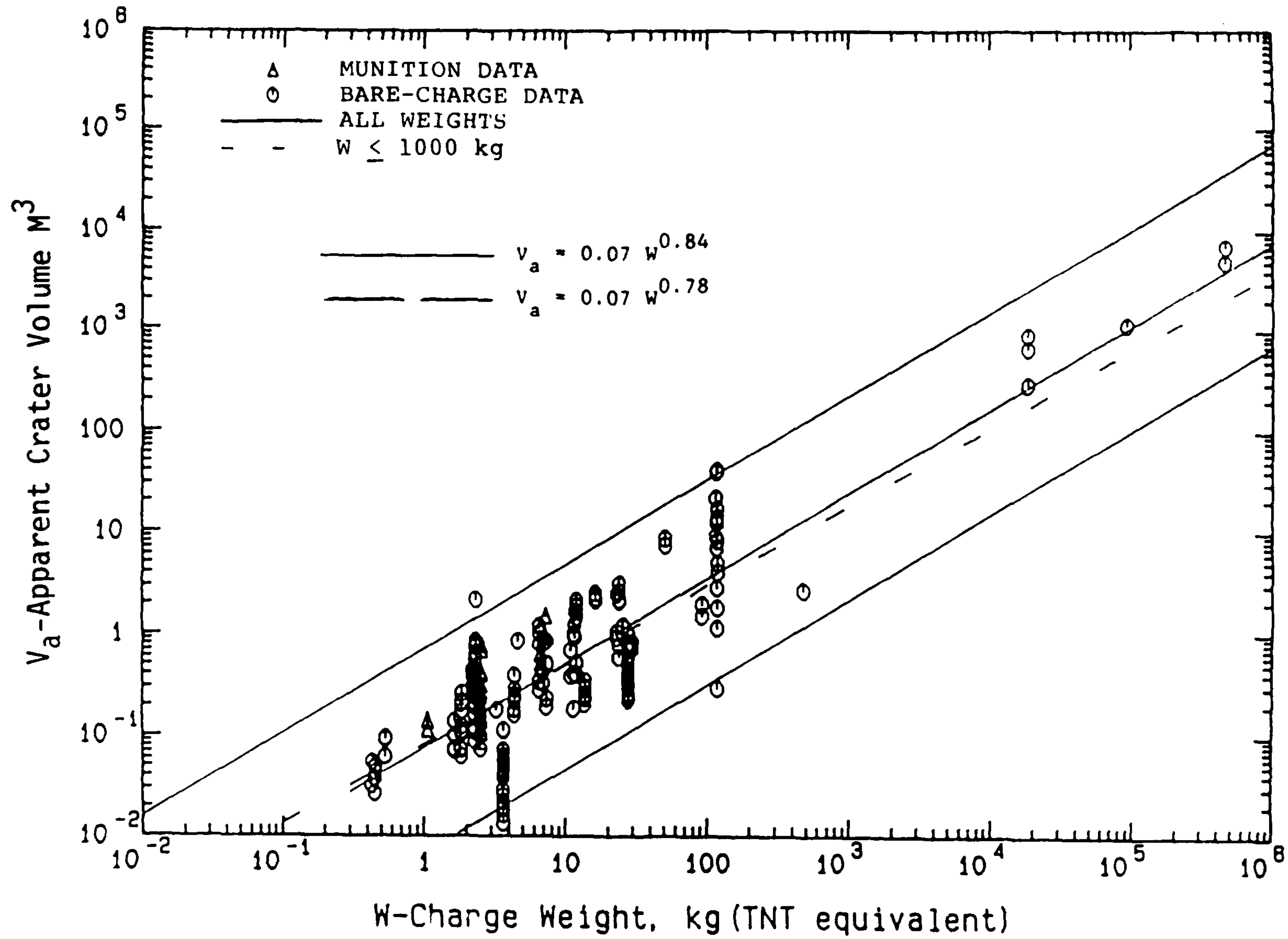


Figure 6. Variation of apparent crater volume with charge weight (all soil types, $0 \le R_c \le 1$). Graph contains 298 data points

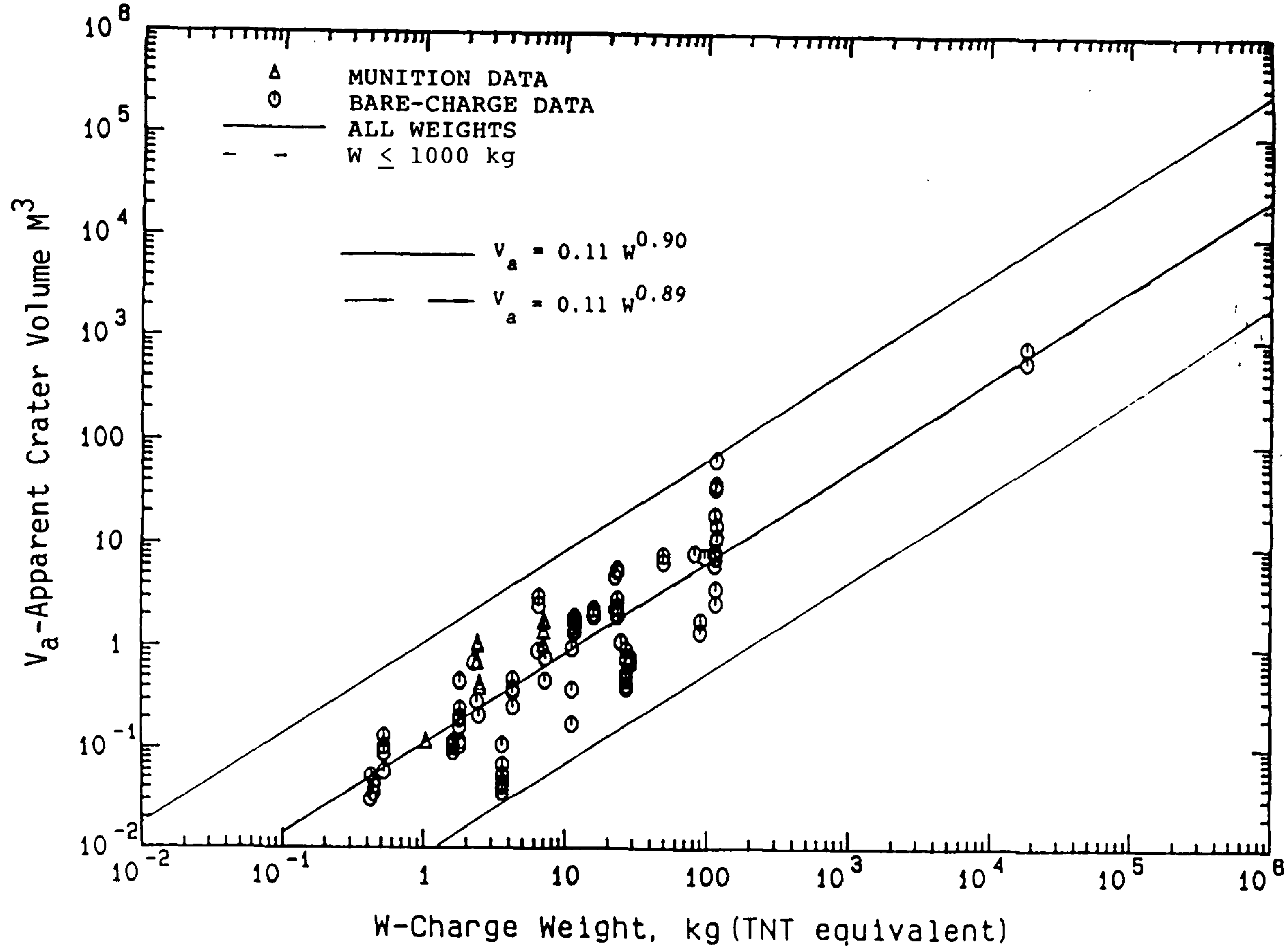


Figure 7. Variation of apparent crater volume with charge weight (all soils types, $-1.0 \le R_c \le 0$). Graph contains 137 data points

only by different ordinate intercepts, i.e., by the multiplying constant C in the basic equation

$$V_a = CW^n \tag{8}$$

Restricted analysis

61. As a practical matter, the most likely occurring charge position for a munition is one near the surface, or air-ground interface, i.e., where $R_c \sim 0$. Figure 8 shows a plot of apparent crater volume versus charge weight for charges positioned such that $-0.5 \le R_c \le 0.5$. The plot shows

$$V_a \propto W^{0.96} \tag{9}$$

Figure 9 shows a similar but more restrictive plot regarding charge position; here, the center of gravity of the charge is at the surface ($R_c = 0$). This relationship is described by the proportional equation

$$V_a \propto W^{0.94} \tag{10}$$

The vertical scatter band in Figure 8 is roughly two orders of magnitude, which is principally a measure of the effect of soil-type variations as well as small variations in charge position. In Figure 9, where the charge position is fixed, the vertical scatter is just slightly greater than one order of magnitude, inferring that the extremities of soil types cause roughly an order-of-magnitude variation in apparent crater volume when the charge position is held constant.

62. All apparent crater volume plots thus far (Figures 5-9) demonstrate that

$$V_a \propto W^n \tag{11}$$

where

$$0.78 \le n \le 0.96$$

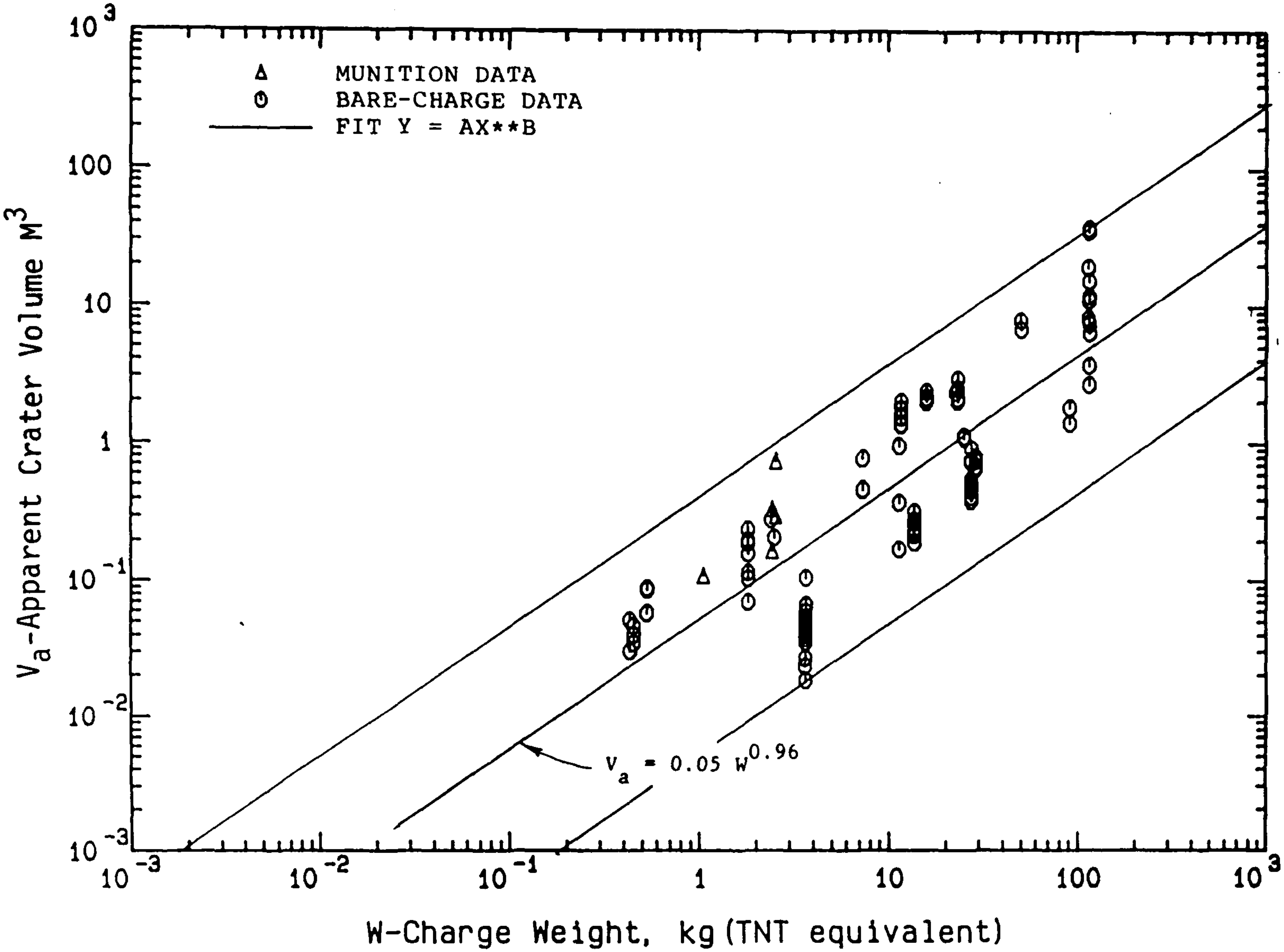


Figure 8. Variation of apparent crater volume with charge weight (all soil types, $-0.5 \le R_c \le 0.5$). Graph contains 113 data points

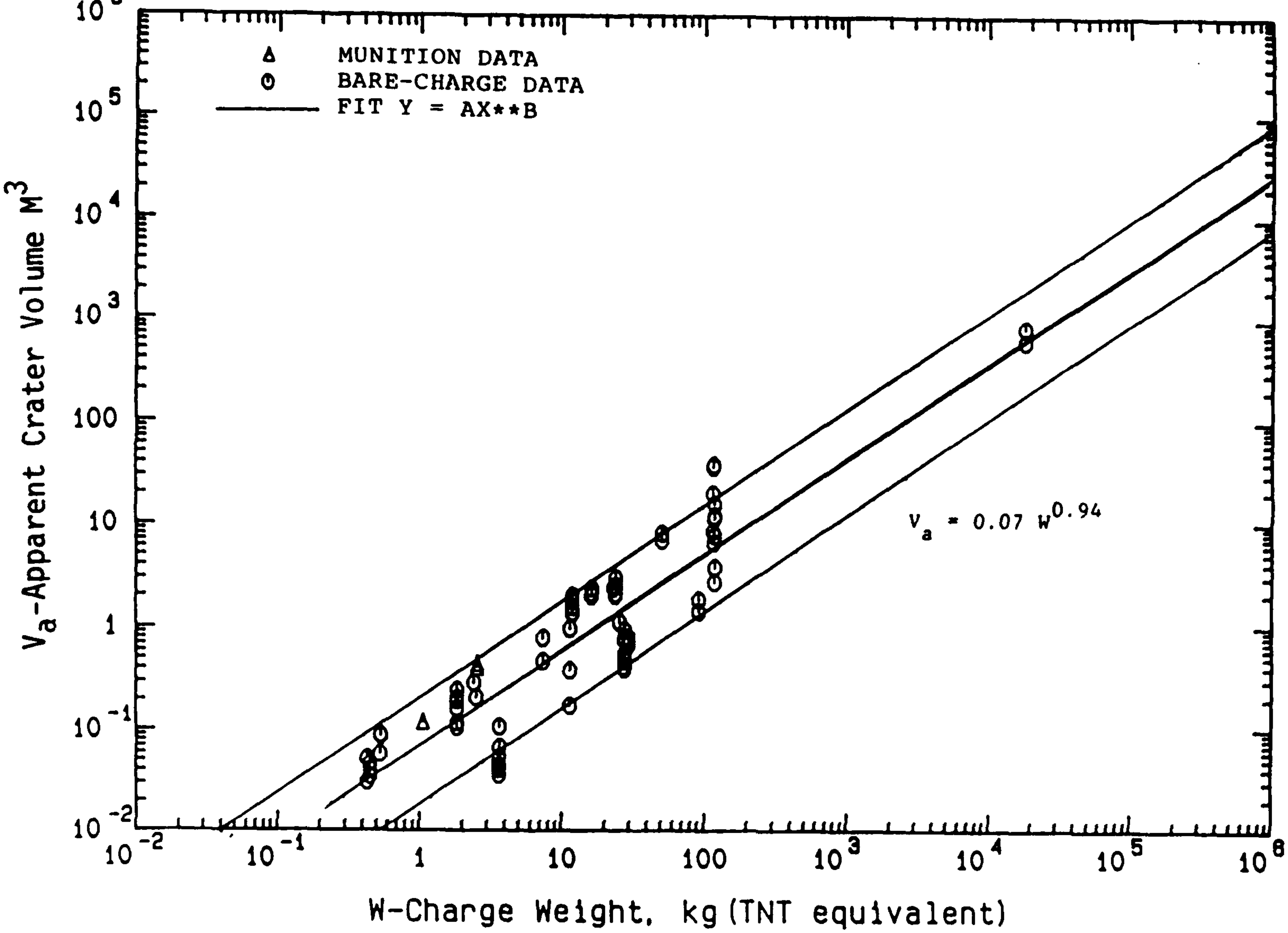


Figure 9. Variation of apparent crater volume with charge weight (all soil types, $R_c = 0$). Graph contains 90 data points

The average value of n, giving equal weight to each plot, is 0.88. A weighted average, based on the number of plotted points in each figure, is 0.86. Considering the scatter in the data at hand and the paucity of data for specific values of R_c, it seems appropriate to calculate VBSSFs for apparent crater volume using 0.87, or an average of 0.88 and 0.86 as the exponent of charge weight rather than the 1.111 that is currently used. Here n is stated to only two significant figures, considered the maximum warranted by the variability within the data base.

Effect of charge
position: similar soils

63. The effect of varying the charge position while holding soil type relatively constant is shown in Figures 10-13, where VBSSFs for apparent crater volume are plotted as a function of charge position for sands (Figure 10), for cohesive soils (Figure 11), for silty soils (Figure 12), and for various rocks (Figure 13). Note that in Figures 10-13 the VBSSFs (ordinate scale) are presented in units of $m^3/W^{0.87}$ rather than the previously used exponent on W of 1.111. The dashed portion of each curve, representing values of $R_c \gtrsim 2.5$, is a "best trend" guess.

64. If the upper bounds of the plots presented in Figures 10-13 are extrapolated to a value of $R_c = -10$, or the burst depth that maximizes apparent crater volume, then the apparent crater volumes that would be obtained for the various soil types are given in the tabulation below for a 100-kg charge and are compared with the stated volume peaks given by Thompson and DeVore (1982) for a charge of equal weight.

Type*	Calculated Apparent Crater Volume, m^3 (from Figures 10-13)	Thompson and Devore (1982): $V_a/W^{1.111}$ Stated Peak Value**	Thompson and Devore (1982): Calculated Apparent Crater Volume, m^3
Sand	55	0.373	62.2
Clay	219	1.68	280
Silt	87	0.553	92.2
Rock	5.5	0.042	7.0

* Sand = dry to slightly moist; clay = wet; silt = moist to near wet; rock = medium hardness.

** Values are in $m^3/kg^{1.111}$.

† Obtained by averaging values for wet sand and moist cohesive soils and dry-to-moist sandy soils.

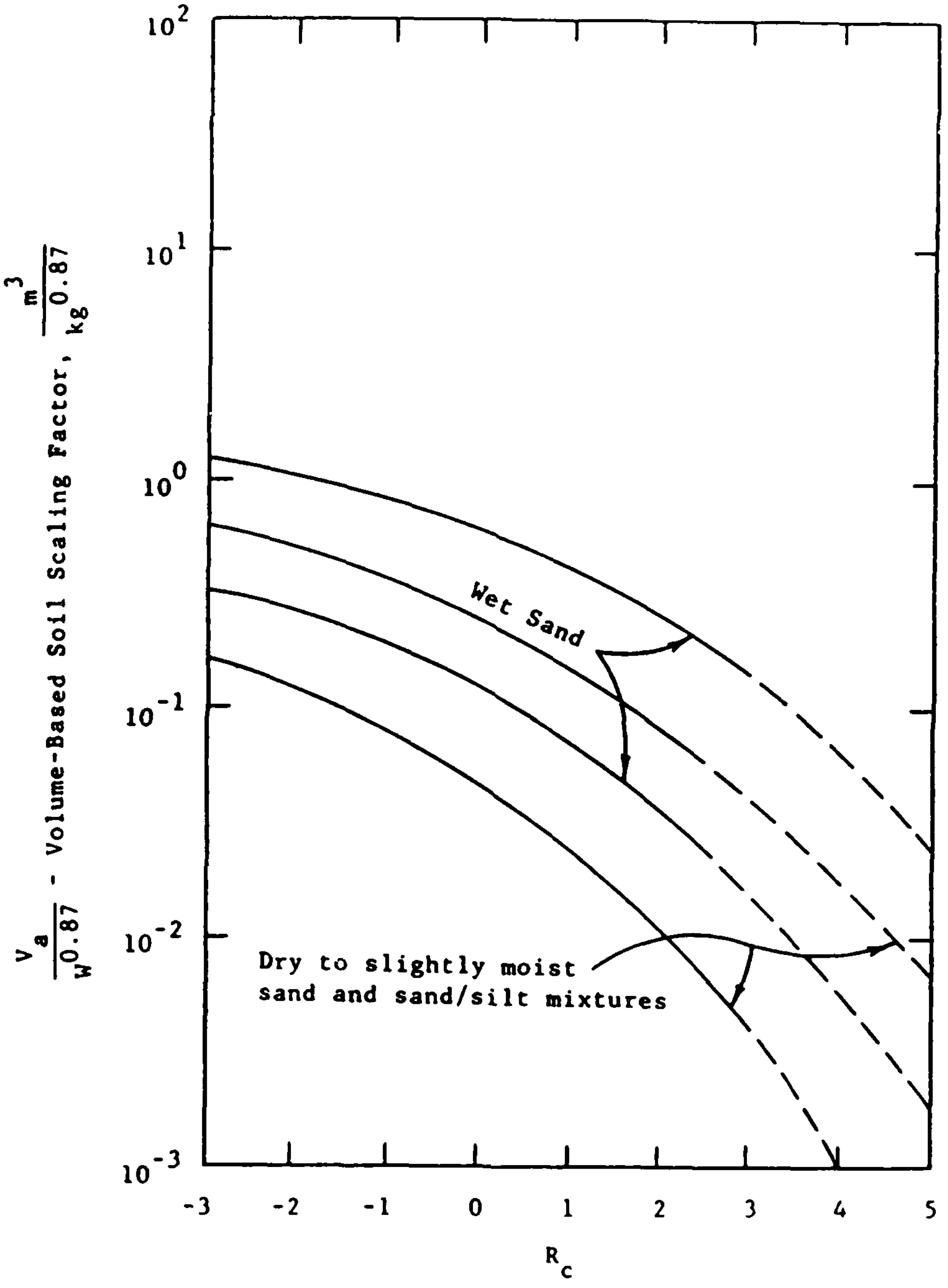


Figure 10. Variation of apparent crater VBSSFs ($V_a/W^{0.87}$) with R_c for sands and silty sand mixtures

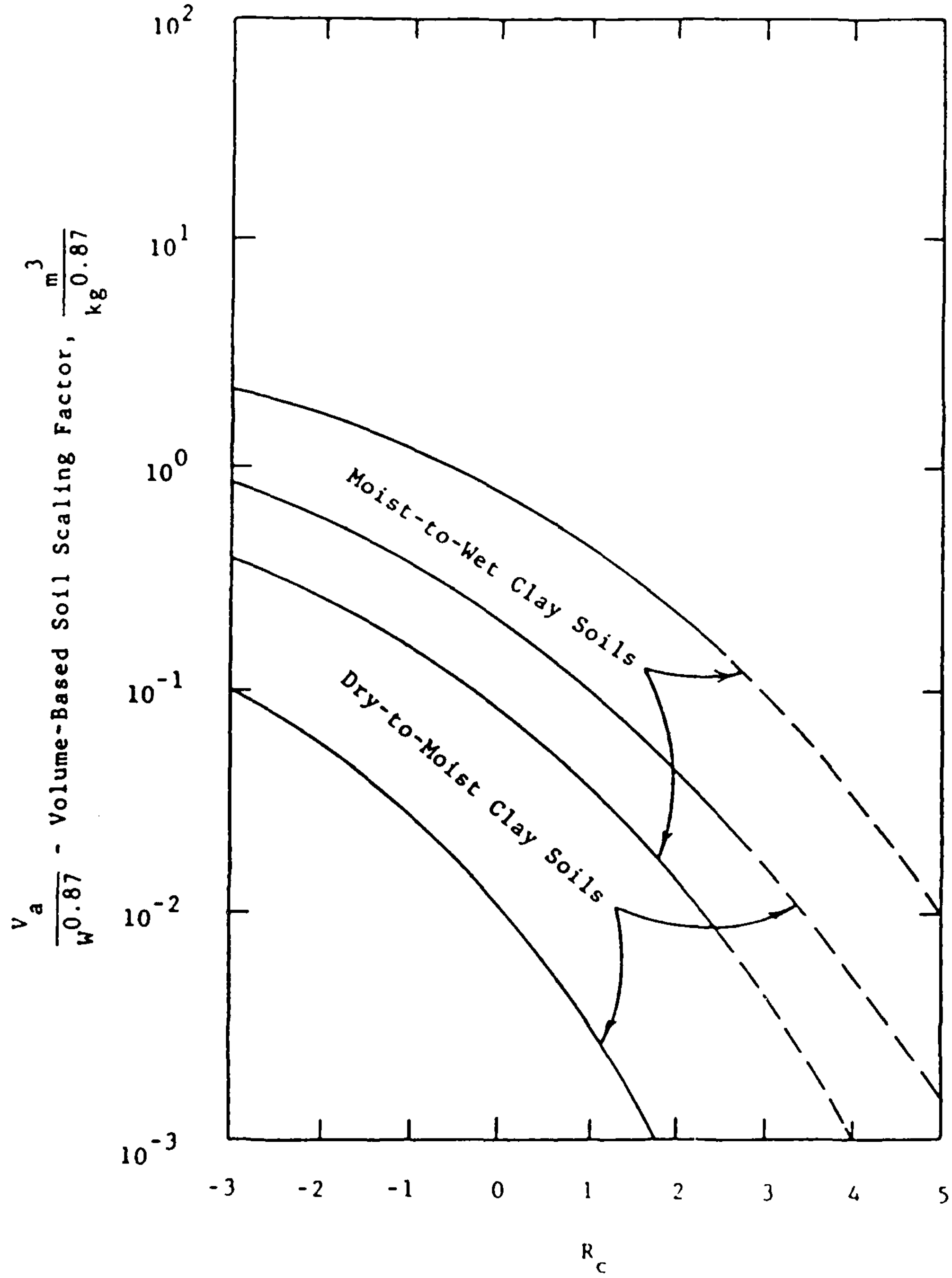


Figure 11. Variation of apparent crater VBSSFs ($V_a/W^{0.87}$) with R_c for soils that are predominantly clay

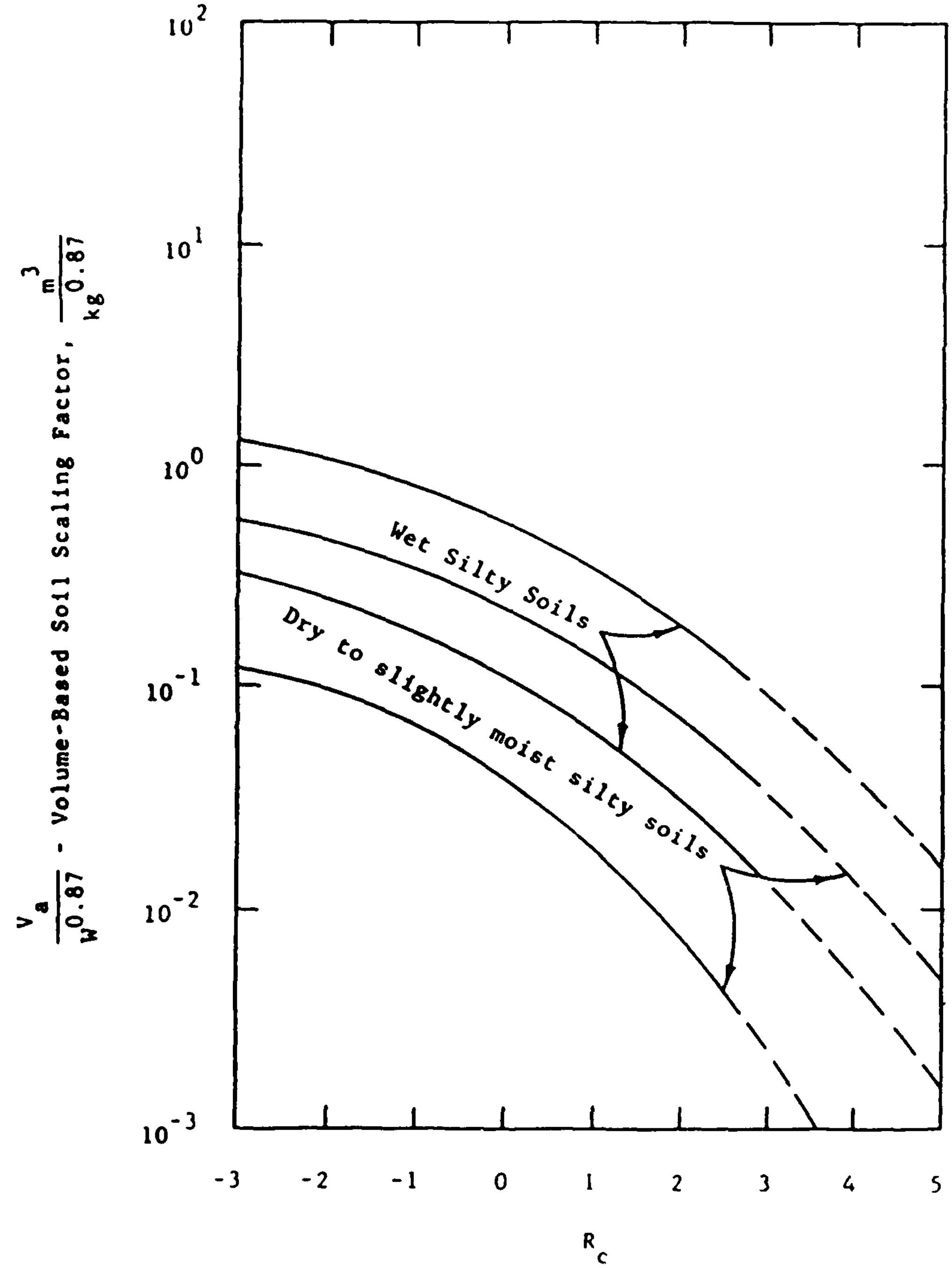


Figure 12. Variation of apparent crater VBSSFs ($V_a/W^{0.87}$) with R_c for silty soils

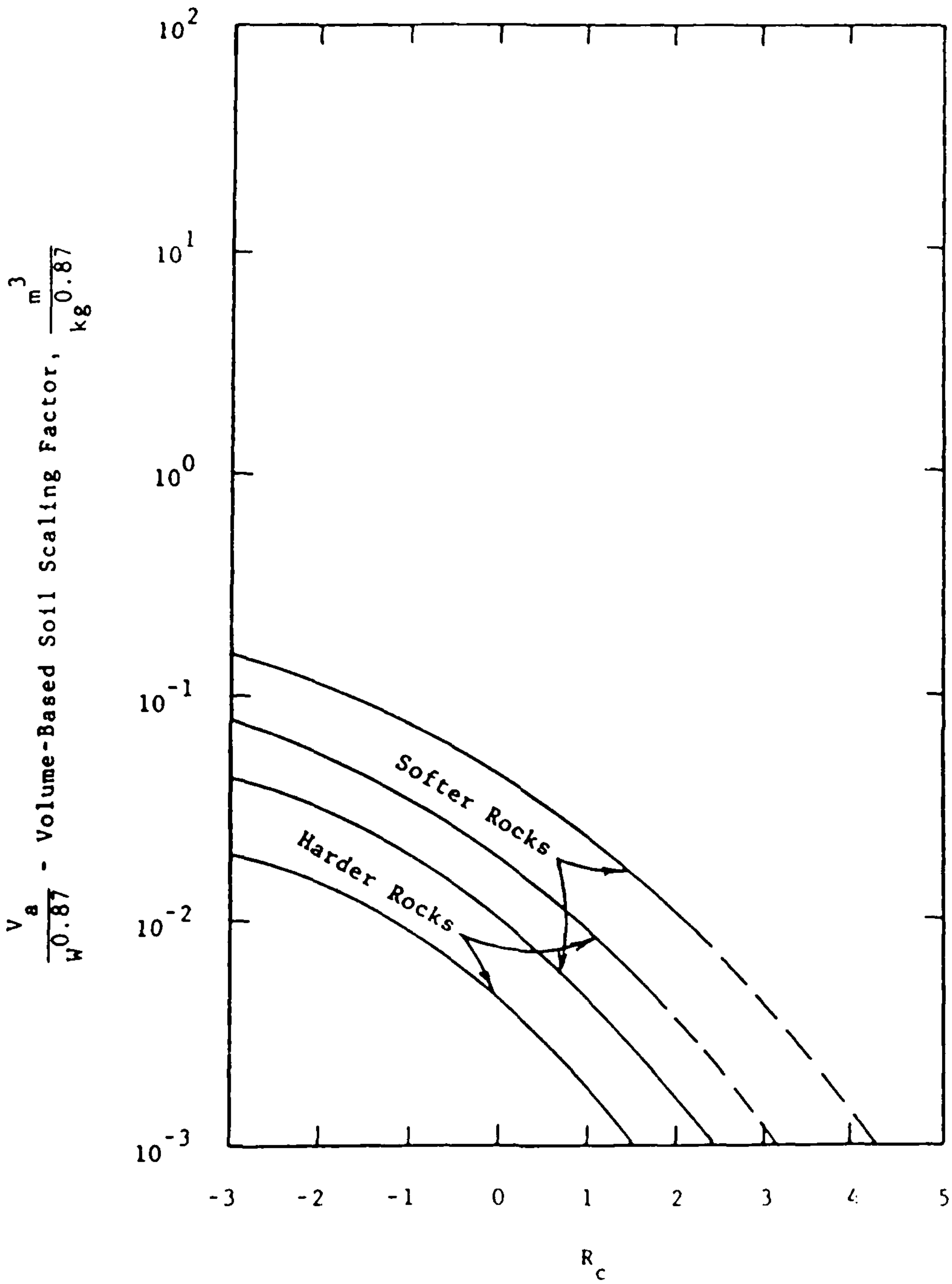


Figure 13. Variation of apparent crater VBSSFs ($V_a/W^{0.87}$) with R_c for various rock types

65. At best, the comparison discussed in paragraph 63 and exhibited in the above tabulation is highly approximate. In the first place, the raw data from which Thompson and DeVore (1982) determined their peak values are not available for direct comparison by plotting. Second, the soil types, although qualitatively similar, may not be sufficiently similar to warrant direct comparison. Nevertheless, the figures obtained differ by less than 30 percent.

True craters:
unrestricted analysis

66. The "all data" plot (no delineation as to soil type or charge position) of true crater volume as a function of charge weight is shown in Figure 14. As seen from the least squares fit equations, the slope of the "all weights" graph is 1.02. For this graph, the true crater volume for the DIAL PACK Event (V_a = 16,300 m^3; W = 454,000 kg) was included. When DIAL PACK is omitted and the charge weight is thus restricted such that $W \leq 1{,}000$ kg, the slope is somewhat steeper, with a value of 1.09. In Figure 14, the scatter is less than two orders of magnitude for a given charge weight.

Restricted analysis

67. Figures 15-18 present plots similar to Figure 14, but for specific ranges of charge position:

Figure	Range of Charge Position
15	$0 \leq R_c \leq 1$
16	$R_c = 0$
17	$-0.5 \leq R_c \leq 0.5$
18	$-0.1 \leq R_c \leq 0$

In these figures, the slopes average 1.03. On a weighted basis (again based on the number of plotted points in each graph), the average is also 1.03. In these figures, the scatter is approximately one order of magnitude for a given charge weight.

68. Over the range of charge weights of chief concern to this study ($W \leq 1{,}000$ kg), the proportional equation is applicable:

$$V_t \propto W^n \tag{12}$$

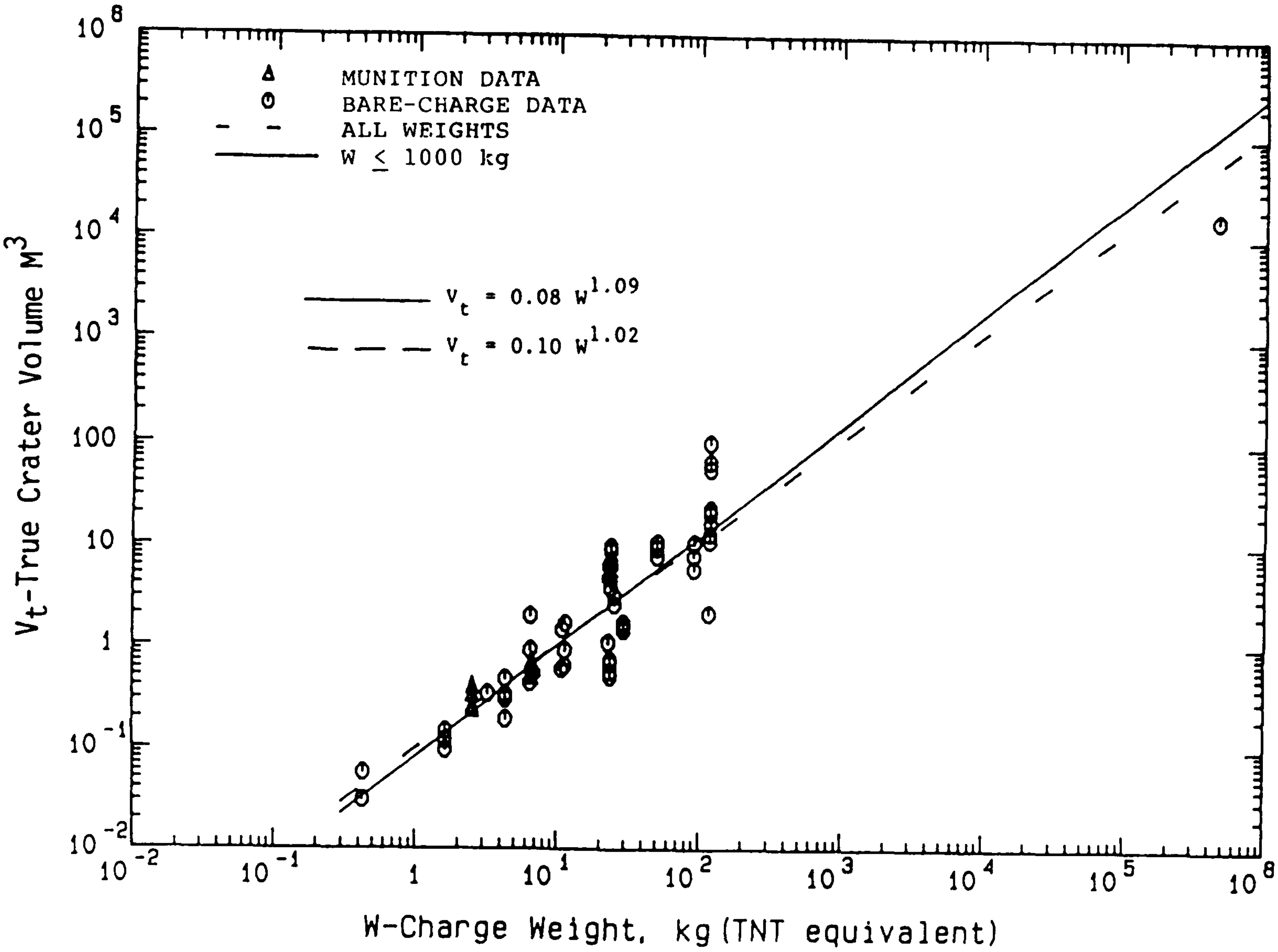


Figure 14. Variation of true crater volume with charge weight (all soil types, all charge positions). Graph contains 69 data points

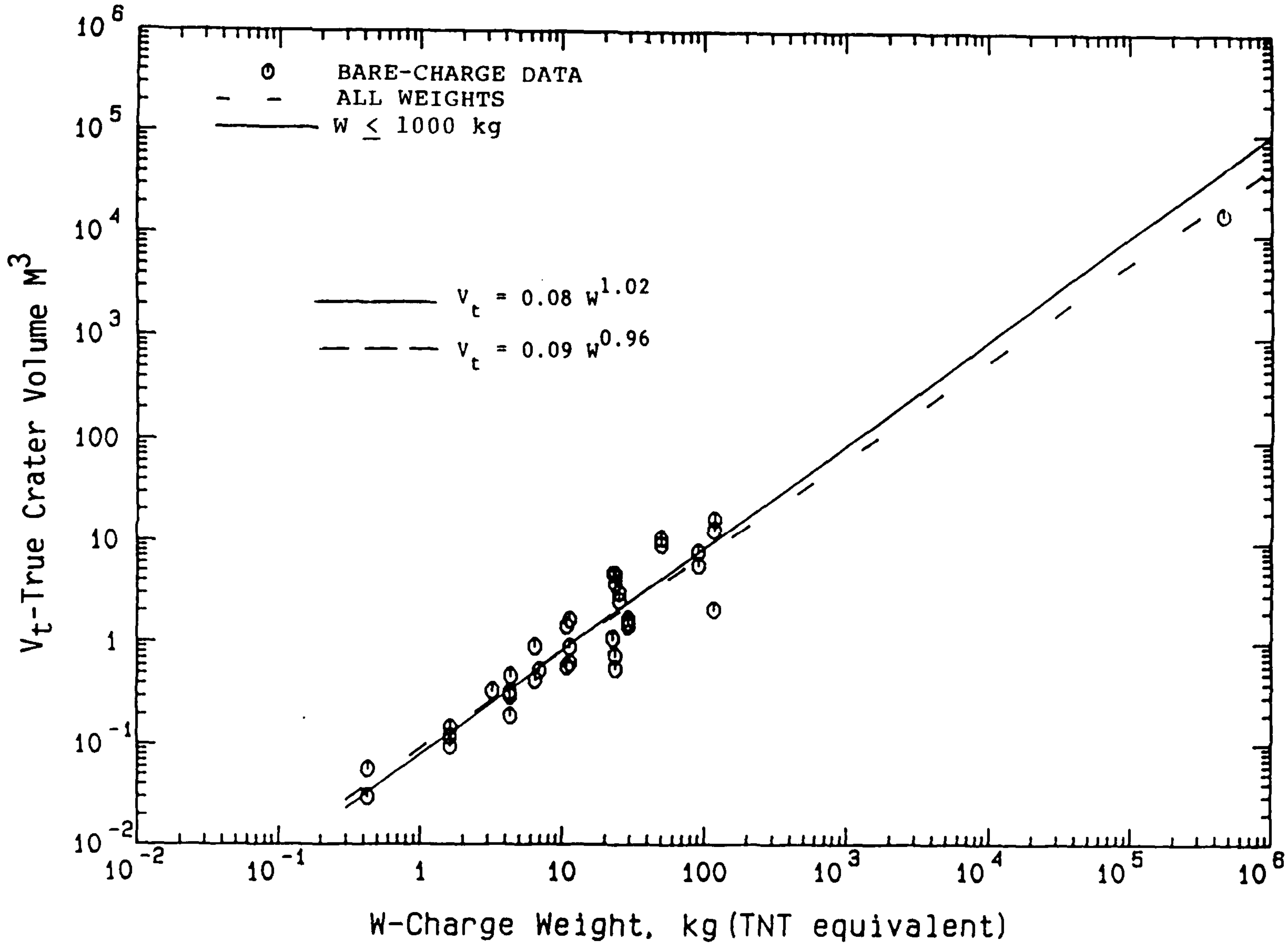


Figure 15. Variation of true crater volume with charge weight (all soil types, $0 \le R_c \le 1$). Graph contains 42 data points

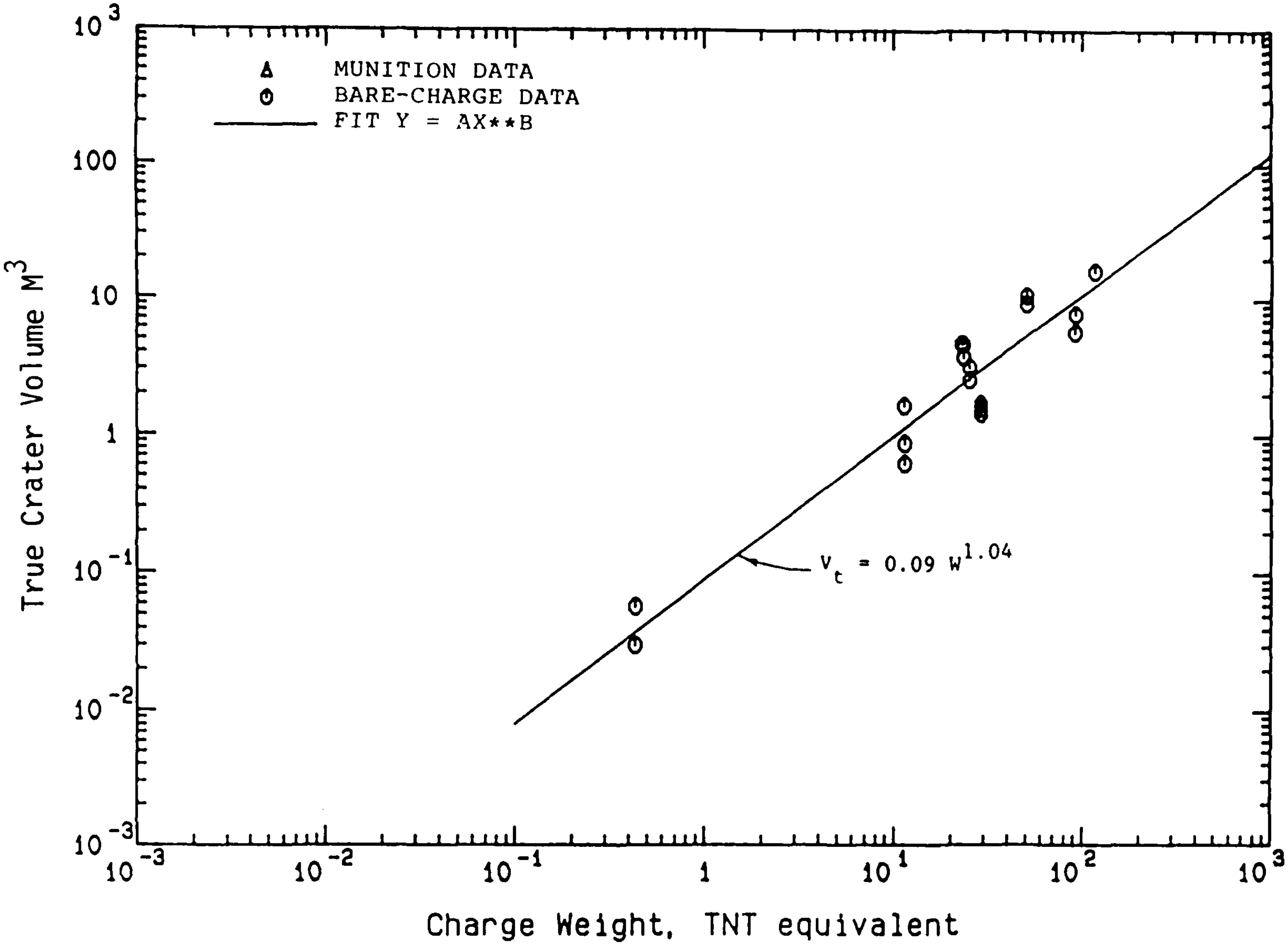


Figure 16. Variation of true crater volume with charge weight (all soil types, $R_c = 0$). Graph contains 21 data points

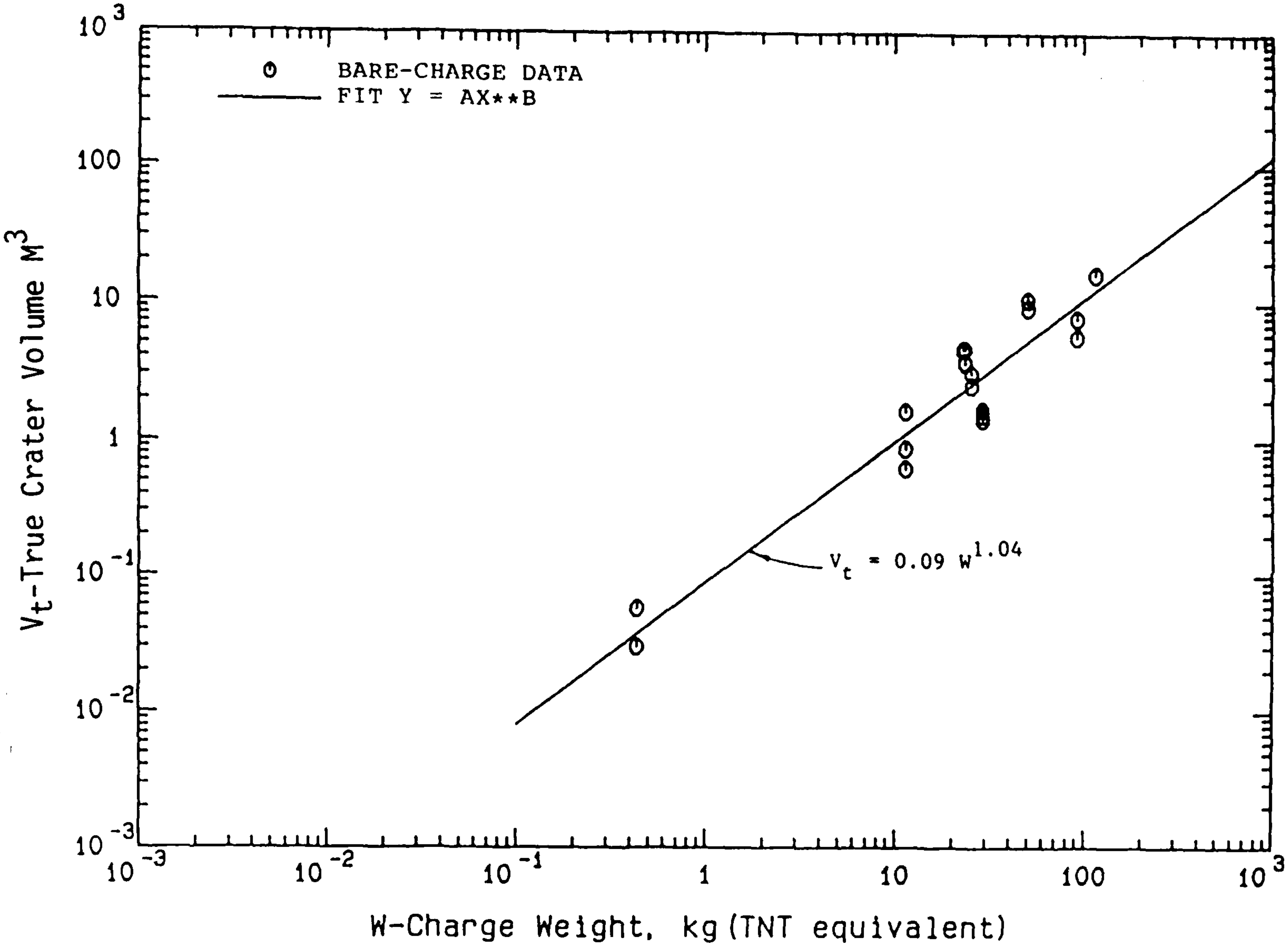


Figure 17. Variation of true crater volume with charge weight (all soil types, $-0.5 \leq R_c \leq 0.5$). Graph contains 21 data points

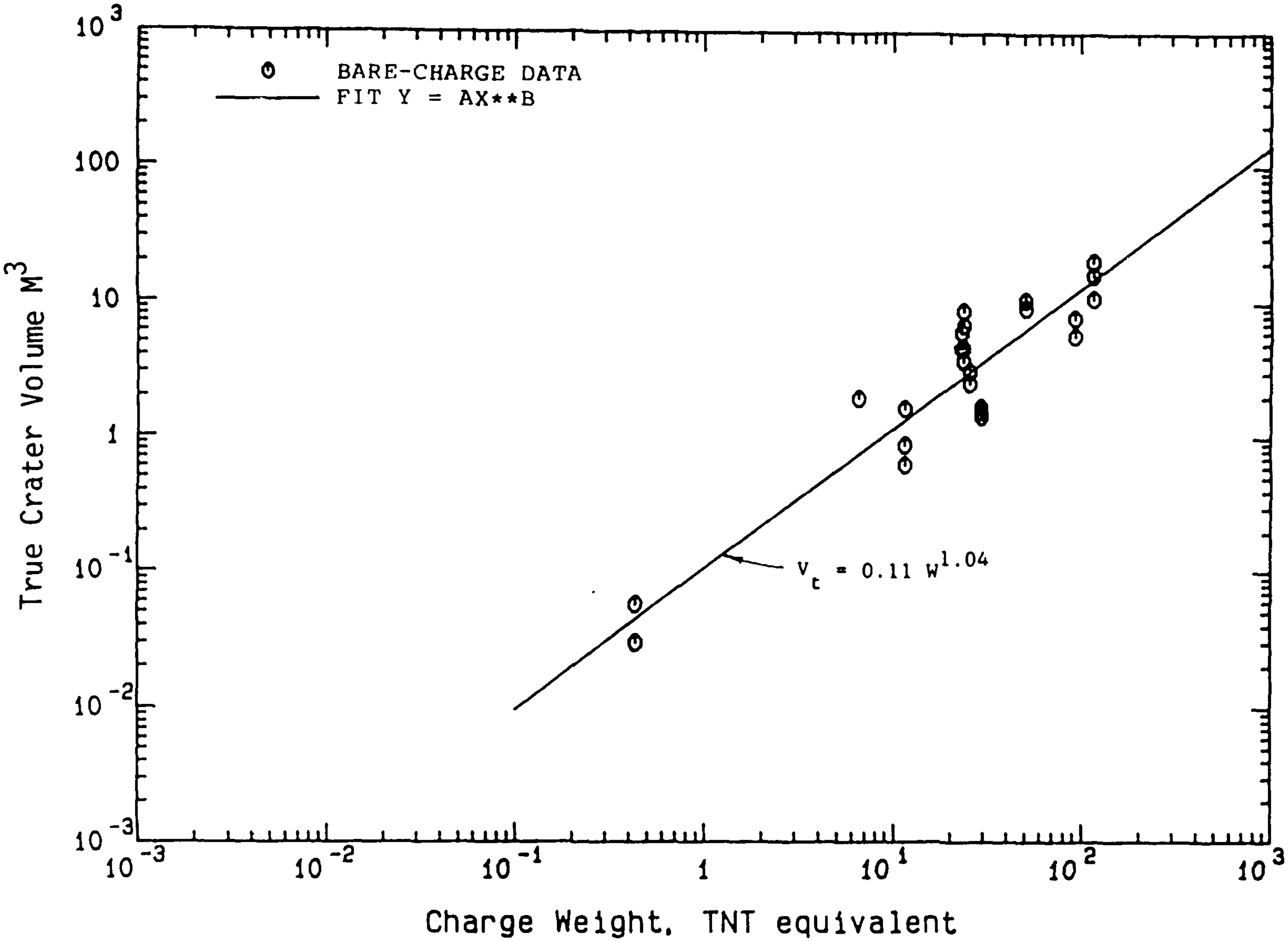


Figure 18. Variation of true crater volume with charge weight (all soil types, $-1.0 \le R_c \le 0$). Graph contains 25 data points

where

$$0.96 \leq n \leq 1.09$$

The average value of n, as determined from Figures 14-18 on a weighted basis, is 1.03. As with the apparent crater data, it is felt that the quoting of a value on n to more than two significant numbers is not warranted. Thus VBSSFs for true craters should be determined on the basis of $n = 1.0$, i.e.,

$$(VBSSF)_t = \frac{V_t}{W^n} \tag{13}$$

where n is assigned the value of unity. This means that for true craters, volume is directly proportional to charge weight, i.e., a doubling of charge weight will have the effect of doubling the crater volume.

69. Figure 19 presents a plot of the true crater VBSSF as a function of R_c without regard to soil type. Lack of true crater data precluded the development of plots for specific soil types as was done for apparent craters. Although not well defined, there is a tendency for moist-to-wet clay data to be in the upper portion of the plot, followed by silts and sands, with rock values plotting near the bottom portion of the data envelope.

Effect of Vegetation on Cratering

70. Quantification of the effect of vegetative cover on the size of the apparent crater is possible only in the case where cratering experiments were conducted at the TTC and for a limited number of experiments conducted by WES. Description of vegetative coverage at other test sites was not adequate to permit comparisons with any degree of confidence.

71. Craters formed by explosions on bare ground as compared with like explosions on or in the same soil type but with grass cover of height less than 30 cm are generally about 10 percent larger by volume. Craters formed on bare ground (as compared with those formed in ground with vegetation consisting of taller grasses, bushes, undergrowth, and small trees, with

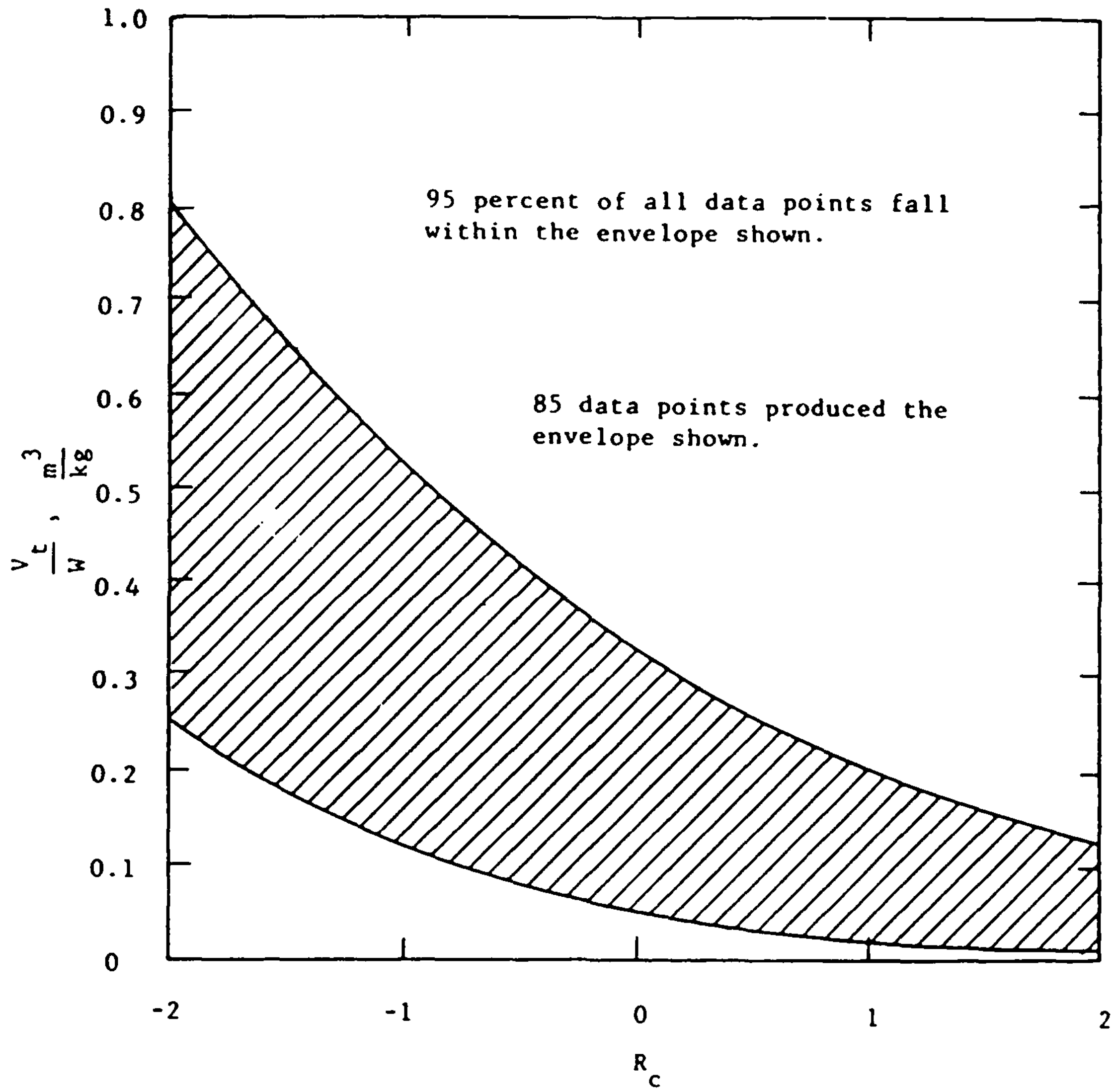


Figure 19. Variation of true crater VBSSFs (V_t/W) with R_c. All soil types are included

coverage approaching 100 percent) are in the range of 15 to 30 percent larger by volume for similar soil types.

72. Ejecta ranges are decreased where concentrated taller vegetation is present; however, the ejecta areal density at close-in ranges is increased.

Effect of Soil Moisture on Crater Volume

73. Unfortunately, there are relatively few cratering experiments in which soil moisture content is adequately described. This fact, combined with data scatter, prevents correlation of changes in crater size with specific moisture contents. Qualitatively though, it was found that soils that were wet but not saturated to the point that slope failures occurred around the crater wall generally produced craters slightly larger than dry or moist soils. For sand, the linear dimensions of a crater are about 5 percent larger for wet than for dry or moist conditions. For silts and clays, the linear dimensions of craters are typically about 10 percent larger in wet soils than in dry to moist soils. These increases in linear dimensions translate into roughly a 15-percent increase in crater volume for craters in sand when wet and dry-to-moist volumes are compared and roughly 25- to 30-percent increase in volume when a similar comparison is made for clays and silts.

74. Cratering in rock, at the scale of interest in this study, is not affected by moisture. Shock transmission in rocks in which pore spaces are filled with water is significantly increased, but available data do not permit an evaluation of how the improvement in shock transmission affects crater size. At the yield levels of interest, it is doubtful that craters in so-called moist rock would be any different from those in dry rock.

Comparison of True and Apparent Crater Volumes

75. The manner in which the ratio of true crater volume to apparent crater volume varies with charge position is reflected in Figure 20. Although the plot shows considerable scatter, the true crater volume approaches the apparent crater volume as R_c becomes increasingly positive and most likely converges at an R_c value near 5 or 6.

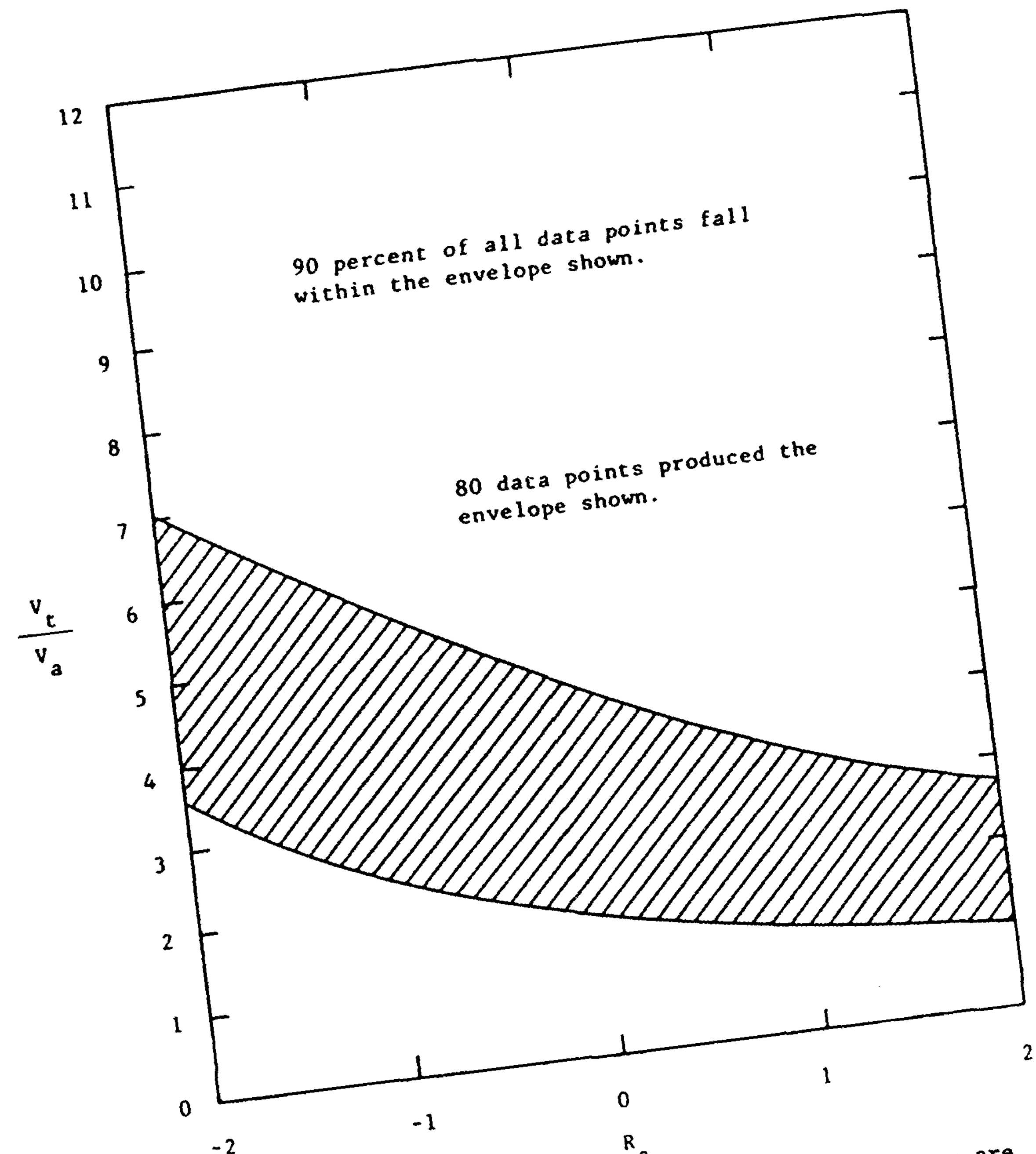


Figure 20. Variation of V_t/V_a with R_c. All soil types are included

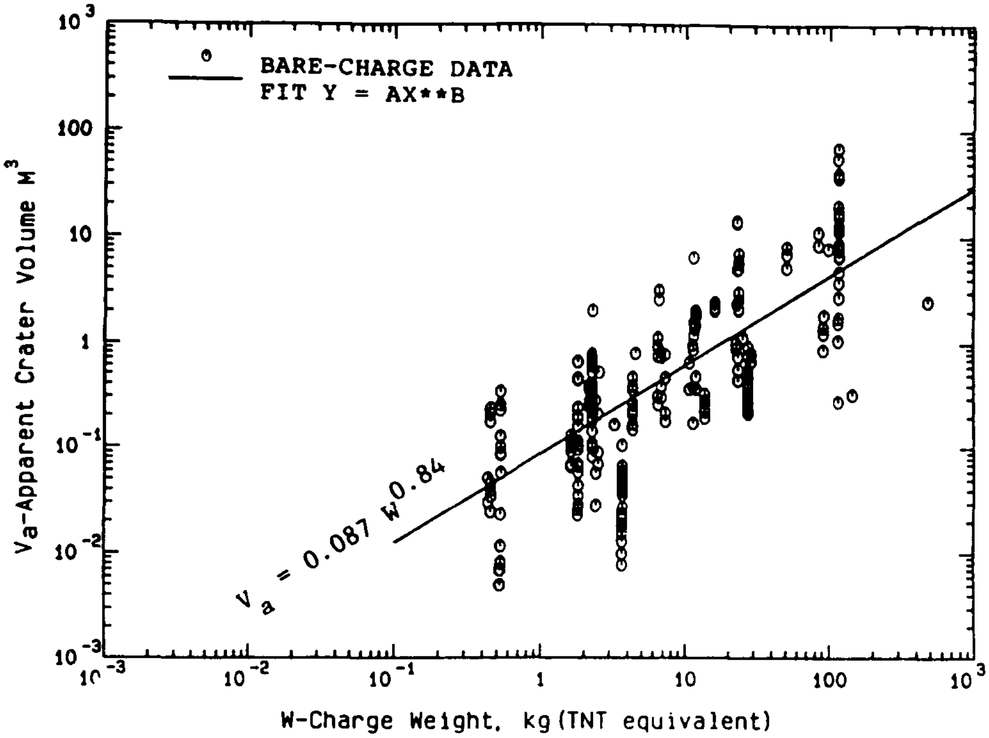
Munitions Craters

76. Crater shape factors for munitions were discussed in paragraphs 52 and 53, where it was shown that, despite the asymmetry typical of munition craters, there is little overall difference between munitions and bare-charge craters when crater volumes are used as the basis of comparison. Figures 5-9 show that apparent crater volumes from exploding munitions fall within the scatter band of bare charges. However, closer inspection reveals some differences between the two, as well as explicit differences associated with the various munitions and their detonation geometries. Some of the differences noted may be due to differences in the soils, especially moisture content. Unfortunately, as with most crater data, the scatter tends to mask these differences and any statistical significance that might be associated with them. The following paragraphs give a detailed discussion of the munitions portion of the data base compiled in this study.

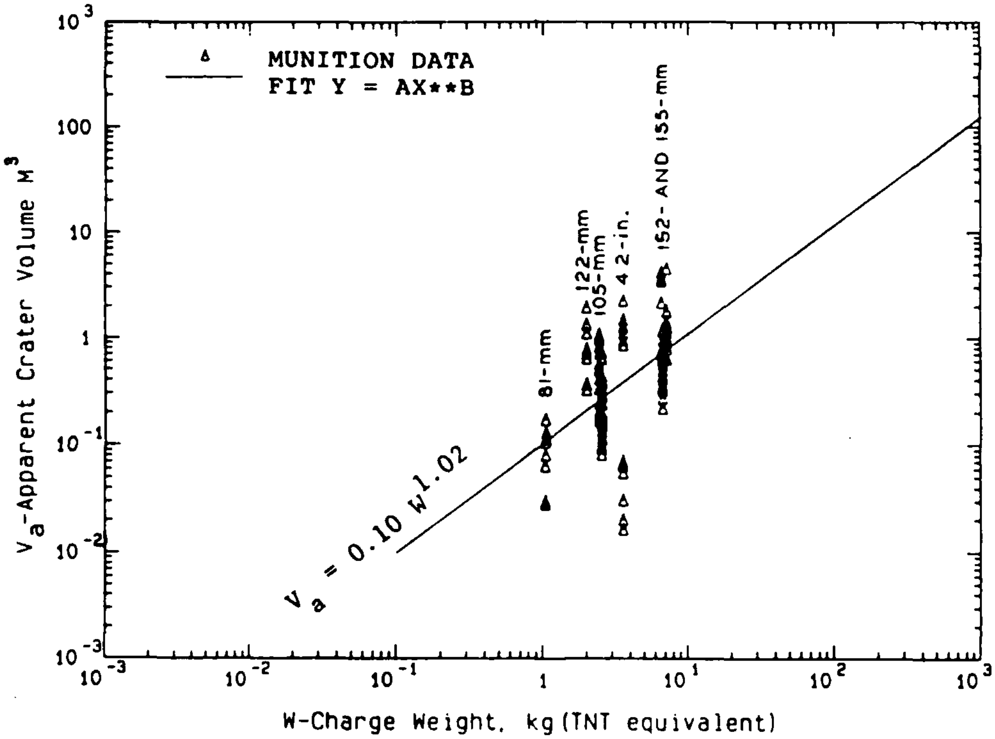
Comparison of Crater Volumes for Munitions and Bare Charges

77. Figure 21 compares volumes for nonmunition (bare-charge) data with those for munitions only. The bottom graph (Figure 21b) is taken from Tables 5 and 9, with a total of 146 data points representing 195 shots (note that one point in Table 9 averages 50 shots). Six munitions are represented, each showing considerable vertical scatter. Part of this scatter is due to the range of detonation geometries. While the "live" fire of Table 9 is all by "fuze quick," i.e., no built-in delay, the static detonations of Table 5 include several different projectile orientations, both above and below ground. Figure 21b may be thought of as representing a band of cratering results from artillery and mortars fired for various effects ranging from antipersonnel (fuze quick) to destruction of fortifications (fuze delay).

78. Perhaps the most severe restriction concerning the munitions data base is evident in Figure 21b, and that is the narrow domain of TNT-equivalent charge weights along the x-axis. This restriction, combined with the y-axis scatter, reduces confidence in the computed data fit. In view of the small variation in x-values, four types of curve fits were examined in detail; Table 11 lists equations and associated statistics for these curves. Of the four, the fit $Y = A + BX$ consistently gave the highest Index of



a. Bare-charge data



b. All munitions data

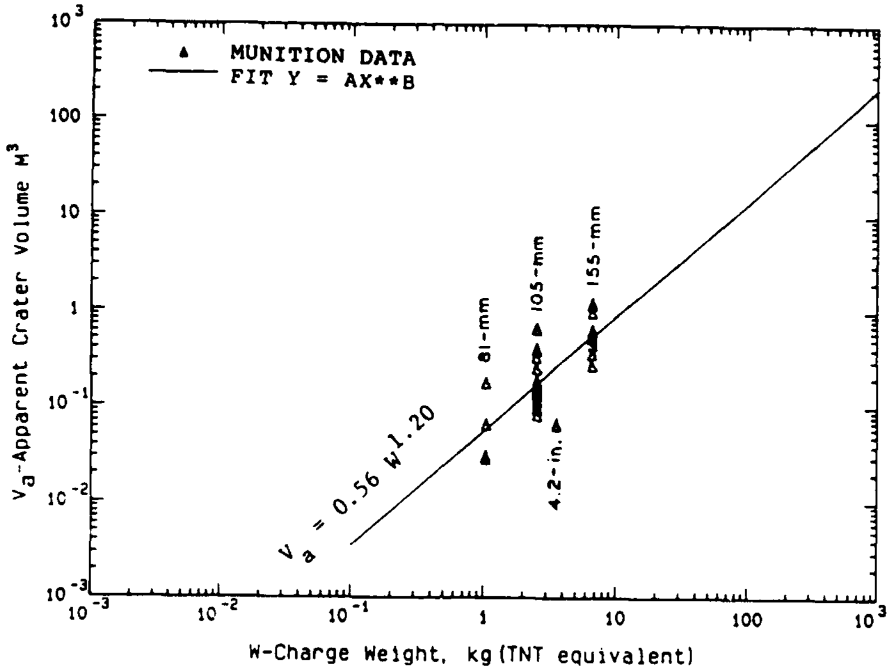
Figure 21. Comparison of nonmunition (bare-charge) and munitions crater data

Determination (I) (see Table 11 for explanation; briefly, $I = 1$ is the best fit possible) in this and subsequent munitions graphs. Visual examination of this fit, however, shows that it is not satisfactory in the lower range of charge weights. Similarly, two other candidate curves were rejected as poor fits at the extremes of the data and thus not suited for extrapolation to higher or lower yields. With these considerations and limitations, the curve $Y = AX^B$ was chosen as the best fit overall for this and subsequent graphs, despite its lower I-value. It should be noted here that all values of I for these fits are low, due to data scatter; as can be seen in Table 11, I ranged from 0.105 to 0.473.

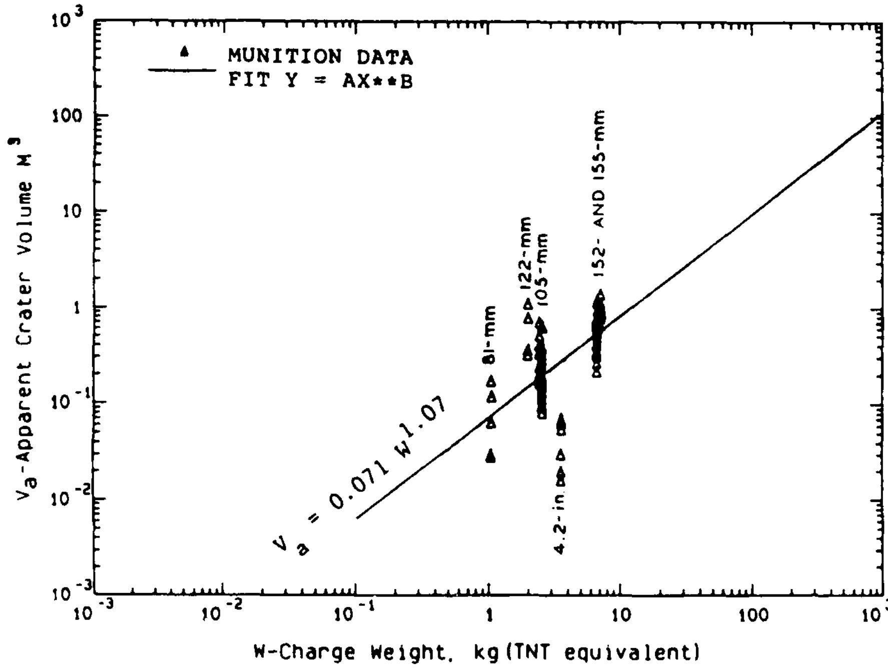
79. In Figure 21b, the results obtained with two munitions bear further comment: these are the Soviet 122-mm projectile and the 4.2-in.* mortar projectile. The 122-mm shell, fired statically in several geometries, gave larger craters than would have been predicted from the data fit. The reason for this is not known, but may have to do with the fragmentation characteristics of the shell. The 4.2-in. projectile provided craters grouped into two distinct sizes, those well above the line from a surface-tangent-below geometry (buried one projectile length) and those far below the line from live or simulated live (fuze quick) firings, where $2 \le R_c \le 4$. The craters for the two conditions differ roughly by a factor of 30, which is mainly attributable to differences in shot geometry. Although the simulated live firings would be expected to have smaller craters, they appear unusually small when compared with the 81-mm projectile. These departures from the $Y = AX^B$ fit should be borne in mind when predicting craters for these munitions.

80. In most cases, live-fire data should give the best representation of cratering that would be expected on the battlefield. However, the data base here is small (34 points representing 83 shots), and, of course, shot-to-shot control is inferior to static firings. The live firings of Table 9 are graphed in Figure 22a, with statistics included in Table 12. Note that the U.S.S.R. 122- and 152-mm projectiles, which could only be fired statically, have not been included. In an attempt to improve upon these limitations, static firings of all munitions that appear to adequately simulate live fire were added from Table 5, bringing the total to 106 data points representing

* A table of factors for converting non-SI units of measurement to SI (metric) units is presented on page 7.



a. Live fire



b. Live plus selected static firings

Figure 22. Comparison of live-fire munitions craters with live fire plus selected static firings that simulate live (fuze-quick) detonations

155 shots; this combination of live plus selected static firings is shown in Figure 22b. Excluded are the events in Table 5 with entries in the MO D/A column of S, STB, 1/3BUR90, and 1/3BUR45.*

81. Artillery projectiles are of particular interest here, both because of their widespread use on the battlefield and because sufficient data are available to permit a closer look. In Table 12, 105- and 155-mm howitzer projectiles fired live or in a geometry that simulated live fire were subjected to additional scrutiny. Several comments are appropriate.

a. In comparing live and static firings at the same test sites, the 155-mm static firings appeared to produce larger craters than the 155-mm live firings, but results were mixed for the 105-mm live and static firings.

b. In the case of the 105-mm, a projectile orientation representing the terminal ballistic path for a longer range, say, 20 deg as opposed to 10 deg, may result in a slightly larger crater. For the 155-mm, the opposite seems to be true. It is speculated that these differences are due to fragmentation patterns.

c. The more saturated soils appear to produce larger craters, as would be expected; however, this cannot be quantitatively established with the data available.

d. The 155-mm shell is roughly 2.75 times as heavy as the 105-mm, both in terms of total weight and charge weight. However, its apparent crater volume for live or simulated live fire is only about 1.7 times as large as that of the 105-mm.

82. In Figure 23, the $Y = AX^B$ curve fits from the preceding discussion (paragraphs 77-80) are compared. As can be seen, the munitions curves are consistently steeper in slope than the "all-data" fit, but are not significantly displaced from it in the charge-weight range of this study. In view of the limited charge-weight range for munitions, as well as theoretical considerations that seem to preclude a slope greater than unity, it appears that the all-data curve provides a satisfactory estimate of munitions-crater volume. A word of caution should be added regarding extrapolation of munitions data, especially upward: the data base of this study consists of relatively heavily cased projectiles; the prediction methodology may not serve as well to predict craters from thinly cased munitions, such as general-purpose bombs.

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* See key to column headings for Tables 1-9 for explanation.

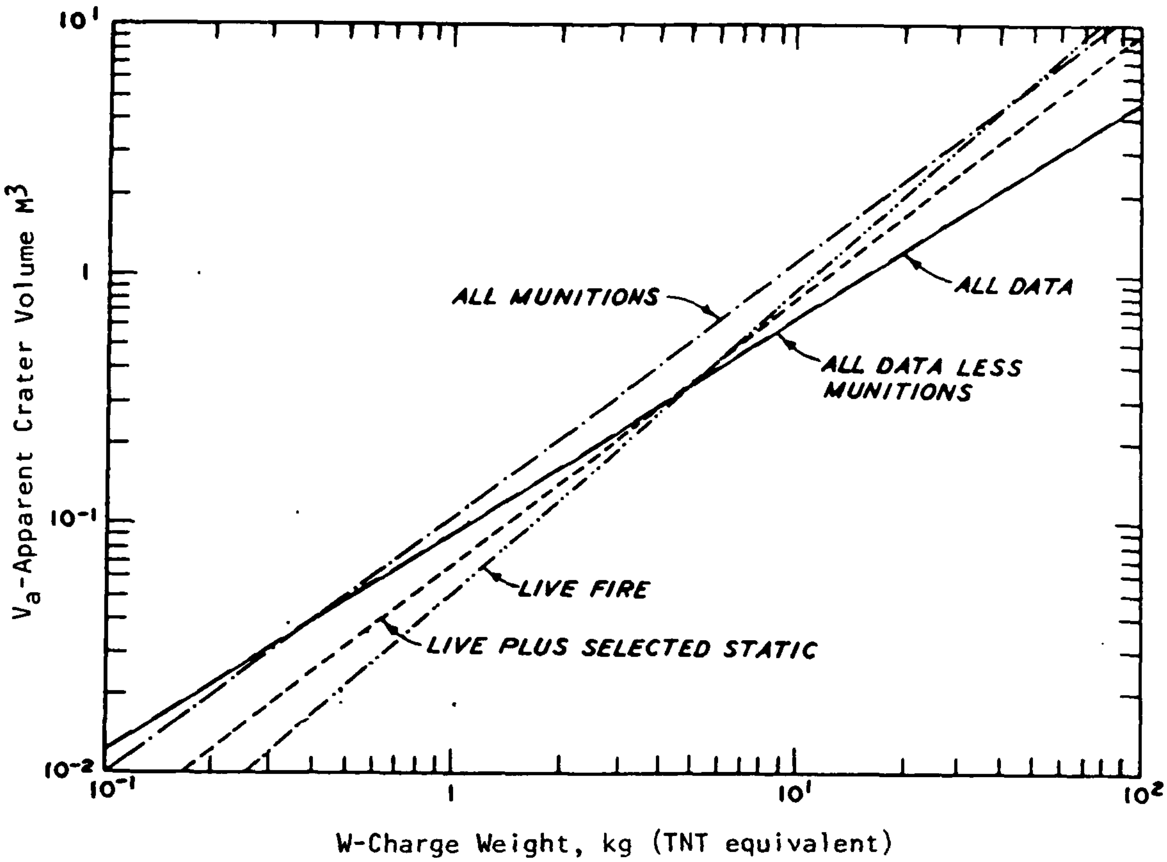

Figure 23. Comparison of $Y = AX^B$ graphs of various munitions and bare-charge data fits. The "all data" and "all data less munitions" graphs are, for practical purposes, coincident

Ejecta Quantities

83. The second major objective of this study was to survey all available data on the cratering effects of point-detonating artillery and mortar shells and on uncased (bare) charges that reasonably simulate the effects of these shells, with the purpose of tabulating those parameters which relate explosive charge size, burst geometry, and cratered medium to the quantity of earth material ejected from the crater. An assessment of this ejecta should hopefully lead to a better estimate of the fraction of this material that comprises the dust cloud resulting from such explosions. Since there are distinct differences between the detonations of HE projectiles and bare charges, tests involving the projectiles themselves should provide the best

data available, and this section examines the ejecta data available for projectiles. Furthermore, live-fired projectiles and those detonated statically in a geometry intended to simulate live fire are considered separately, since some differences in cratering between these two cases have been tentatively identified (Figure 23). As will be seen, only one live-fire event is suitable for analysis of ejecta.

84. Despite volumetric similarities, there are basic differences in the cratering mechanisms of cased and uncased charges and, to a lesser extent, between live and static firings of projectiles. Since these differences affect the ejection mechanism, they are briefly discussed here.

a. Bare-charge craters are formed principally by the explosive shock wave, which tends to crush and compact the cratered medium, and by the expanding explosion-gas "bubble," which follows immediately behind the shock wave, scouring loosened material and, in the case of a buried or partially buried charge, heaving earth material from the crater. By contrast, a cased-charge crater is mostly the result of the kinetic energy of the case fragments as they dislodge the soil. It has been shown that over 80 percent of the charge energy is used in rupturing the casing, and this neglects the strain energy that is expended as the casing expands to its limit before rupture (Batchelor 1963). The fact that craters from bare and cased charges are comparable in size for similar charge weights and positions indicates that the kinetic energy of the fragments is roughly equal to the energy "envelope" of the bare charge in the cratering process.

b. The asymmetries typical of projectile craters have already been discussed (see Figure 3). Reasons for these asymmetries are fairly obvious when consideration is given to the position of the explosive charge at the time of detonation, the projectile orientation, and the fragmentation pattern. Apart from the differences in profiles, craters from bare and cased charges differ in three respects: (1) lack of a well-defined, symmetrical lip for the cased charge; (2) the fact that the bare-charge crater displays significant plastic flowage as evidenced by its upthrusted lip (Figure 2), while the cased charge does not; and (3) the fact that fallback material is not as noticeable in the cased-charge crater. The loosened material is there, however, as a thin covering of the floor and walls of the crater. The overall effect is to complicate the task of assessing ejecta quantities for projectile craters.

c. As to craters from live and statically fired projectiles, there is one major difference: the live-fired shell with fuze-quick setting imparts to its fragments a velocity component along the projectile path, which does not occur in the static firing. As the live-fired shell impacts the ground, fuze detonation occurs within a matter of 5 to 10 μsec, during which time the fuze is

penetrating the earth. Although deceleration has begun, the projectile retains most of its terminal velocity at the time of detonation. For an artillery shell, this may be on the order of 300 to 400 m/sec; for a mortar shell, about half this velocity. The forward velocity component thus added to the shell fragments probably enhances true-crater size, when compared with a static projectile placed so as to duplicate the live shell at the instant of detonation. This increase may not be noticeable in the apparent crater, however; overall differences in crater sizes between the two conditions are usually small.

85. It is worth noting here that, for both live- and static-fire cases, many fragments impact beyond the confines of the crater, and these fragments are an additional source of dust not included in a crater study. The effect of such fragments may be observed in an artillery low airburst over dry soil, where no cratering occurs but where a large dust cloud is formed.

Live-fire projectile data

86. Table 9 contains data on live-fire tests known to the authors. Included are data from 81-mm and 4.2-in. mortars and 105- and 155-m howitzers. While the table is intended to be mostly self-explanatory, some comments on its composition are in order. Most importantly, it should be noted that nowhere in any of the data for live or static firings were crater-ejecta weights or volumes explicitly given. However, there are a number of tests in which sufficient data were furnished to permit calculation or at least reasonable inference of ejecta weight or volume. These calculations or inferences then became the basis for certain parametric relations that were extended to other test results. In the live-fire table, the experimental investigation of Shot T-27 provided enough information for a volumetric balance of the crater (explained in the following paragraph), the only such balance that could be accomplished for live fire.

87. If crater-ejecta volumes are not measured directly, as by sampling, they may be inferred by "balancing." Crater volumes may be balanced by the following expression:

$$V_t = V_e + V_{fb} + (V_c + V_{f\ell}) \tag{14}$$

where

V_t = true crater volume (see Figure 3)

V_e = volume of ejecta

V_{fb} = volume of fallback material

V_c = volume created by compaction

$V_{f\ell}$ = volume created by plastic flowage into the crater lip

As stated here, all volumes are in situ (in the undisturbed state). Fallback is usually measured in its bulked form, and experience has shown that reduction of this as-measured volume by a factor of about 1.5 approximates its in situ volume. The grouping $(V_c + V_{f\ell})$ indicates that these volumes are seldom measured separately. Equation 14 permitted a balance of the volumes of Shot T-27, from which the relation $V_e = 0.22\ V_a$ was derived, V_a being the apparent crater volume. As will be shown, this relation is probably too small.

88. The explosive filler used in a projectile may differ significantly from the usual energy standard, TNT, and thus should be considered in any assessment of cratering results. The projectile explosive charge in Table 9 is listed by actual type explosive and weight and by TNT equivalence. In this case, TNT equivalence is taken as that for blast and impulse, since it is these properties that contribute to fragmentation of the shell case. For example, the 81-mm mortar projectile contains 0.95 kg of Composition B, which is 1.10 times as effective as TNT in blast and impulse and is therefore considered equal to 1.05-kg TNT for this study (Headquarters, Department of the Army 1955).

89. To visualize the geometry of the explosive charge in relation to ground surface, an equivalent charge radius R_c based on a sphere of TNT of equivalent yield is used, as it was in the discussion of bare charges. This facilitates comparison of shot geometries. Actually, projectile charges are roughly cylindrical in shape, but the transformation to a sphere in concept does not appreciably affect shot geometry. Using an average specific weight for TNT (about 1,522 kg/m^3 or 95 lb/ft^3), $R_c = 0.0539\ W^{1/3}$, where W (charge weight) is in kilograms and R_c is in metres. For the small charges involved in this portion of the study, a more practical approach might be to consider R_c in centimetres, in which case $R_c = 5.393\ W^{1/3}$. Thus, height (depth) to the center of gravity (CG) of the cased explosive charge can be

expressed in terms suitable for comparison with bare charges for the various projectile orientations. Actual CG of the charge within each projectile is estimated from scaled drawings (Headquarters, Department of the Army 1967).

90. Shape factors used in calculation of projectile-crater volumes (and, thus, inference of ejecta volumes) were discussed in paragraph 53 and shown in Figure 4. Unlike the bare-charge craters, these shape factors exhibit a wide variation for different munitions, sites, and shot geometries and for live and static firings.

Statically fired projectiles

91. As mentioned earlier, live-fire tests are somewhat difficult to control and measure, and static firings are often substituted to obtain crater/cloud measurements. For this purpose, it is necessary to assume a projectile geometry that would occur in live fire. The angle of impact can be taken from firing tables and is found to be around 15 to 20 deg for ranges (distances) at which howitzers frequently fire and 70 to 80 deg for mortars. If fuze-quick action is assumed, then penetration of the fuze into the earth can be estimated as less than 1 cm at the time of detonation. This means that the body of the howitzer projectile (at the base of the fuze) is very nearly in contact with the ground when detonation occurs and that the mortar shell is several centimetres aboveground. For the howitzer shell, this convenient assumption means that the fuze can be removed, a blasting cap and booster charge inserted, and the shell placed on the ground and tilted to the desired angle for the static test.

92. In general, the comments applicable to live-fired projectiles apply also to static firings. There are, however, some differences and some additional considerations. Table 5 contains static-fire data on the same (US) projectiles as Table 9 and, in addition, data on Soviet 122- and 152-mm projectiles. Information on the U.S.S.R. projectiles was not as complete as for the US shells, and calculations of charge position may be less precise. The range of test geometries included is from simulated fuze quick (referred to as "surface tangent") to one in which the projectile is buried to a depth equal to its own length along an assumed trajectory path, or "surface tangent below" ground. Inclusion of buried or partially buried projectile tests provides cratering data for cases in which fuze functioning is slower than the "superquick" action of modern US fuzes. A range of assumed impact angles is also included. For the WSMR tests, where no projectile shape factor could be

correlated, the bare-charge shape factor discussed in paragraphs 45-48 was used to calculate crater volume.

93. Probably the most important difference between Tables 5 and 9 lies in the assumption of the V_e/V_a relation for the estimation of ejecta volumes. This fraction was calculated wherever possible for both munitions and bare-charge craters and was used to arrive at ejecta volumes where no better method could be found; it is shown in Tables 1-9 under "Ejec Cal." An unusually complete experiment of the US Army TTC enabled both direct calculation of ejecta volumes (explained in paragraph 94) and volumetric balancing on a number of static-fire munitions craters. Table 13 lists important parameters and statistics resulting from these calculations. Similar V_e/V_a relations were calculated for bare charges and will be discussed later.

94. The direct calculation of ejecta volumes mentioned previously is made possible by the sampling of ejecta deposited around some of the craters in the TTC tests. From these samples, average "areal density" δ was calculated for each sampling range R, excluding organic material in the samples. By means of a least squares fit, areal density for the entire ejecta field could be expressed in the form

$$\delta = C\,R^{-m} \tag{15}$$

where C is a constant and the exponent m is the slope of the logarithmic straight-line fit. Equation 15 is probably the most used approach to quantification of ejecta from samples. It can be easily integrated to solve for ejecta weight W_e as follows:

$$W_e = 2\pi \int_a^b (C\,R^{-m})\,R\,dR \tag{16}$$

where the limits a, b are the limits of the ejecta field. The crater rim (r_a) is usually substituted for a, while the outer limit, if not known (as is the case here), can be taken as infinity with little error. The TTC report included soil dry densities, from which wet densities were calculated and used to convert W_e to V_e.

95. Unfortunately, a problem that was encountered in the use of Equations 15 and 16 limited their usefulness. The form of Equation 15 is such that, to employ the $u^n\ du$ integration, the exponent m must be less than -2. This is usually the case in bare-charge craters, where the well-defined lips make for a fairly steep decay of the ejecta field. For the projectile craters, however, a lip is almost nonexistent, and fewer than half of the events on which sampling was done resulted in equations that could be integrated by means of Equation 16. For such cases, a second approach to ejecta areal density has been used. This equation states

$$\delta = A\ e^{-BR} \tag{17}$$

where A and B are constants. Experience with large bare-charge craters has shown that Equation 17 underestimates the ejecta profile in the crater lip, but it was not known whether or not this would be a problem with the munitions craters. In view of the need for additional data, those events on which ejecta sampling was conducted but which could not be evaluated by means of Equations 15 and 16 were placed in the form of Equation 17. For these events, integration by parts was necessary to find ejecta weight. Thus,

$$W_e = 2\pi \int_a^b A\ e^{-BR}\ R\ dR \tag{18}$$

96. Table 5 shows the areal density equations applicable to the various TTC events. In most cases, evaluation by Equations 17 and 18 resulted in smaller ejecta quantities than for Equations 15 and 16. Based upon volumetric analyses, it appears that Equations 15 and 16 give the better estimates; however, all data have been included in the analysis leading to the selection of a V_e/V_a fraction for the TTC shots--a fraction that was applied to all static-fire events for which no better information was available.

97. The TTC study also included explosion-cloud (dust plus explosion gases) data. While there is no attempt here to address cloud dynamics, Table 5 does include maximum recorded areas of cloud obscuration measured from ground stations at some time (seconds) after detonation. Also shown are

vegetation and canopy-cover descriptions, since these may influence both the cloud and ejecta deposition.

98. One further comment on the TTC data is in order: placement of the projectiles was accomplished by means of prefabricated, wooden stands to provide a firm base and the desired angle. It seems very likely that the stands absorbed some of the fragment kinetic energy and thus probably modified crater formation and ejecta deposition to an unknown degree (but believed to be small).

Uncased charges

99. Bare-charge craters intended to simulate projectile detonations provide the final source of ejecta data. As with projectiles, the preferred method of ejecta-volume calculation is by ejecta sampling, available in a number of the bare-charge tests. Where this method is used, areal-density Equation 15 is shown in Tables 1-4 and 6-8, along with calculated ejecta weight (Equation 16) and V_e, found by dividing W_e by wet density. It should be noted here that questionable results, resulting from anomalous samples have been discarded.

100. The second method of ejecta-volume calculation is by volumetric balance (Equation 14), discussed in paragraph 87; this method is possible where true-crater measurements have been made. In the case of bare-charge craters, however, a better understanding of crater volumes enabled some approximations that could not be reliably made for projectile craters--approximations which permitted V_e estimates that would not otherwise have been possible. These approximations began with a rearrangement of Equation 14:

$$V_e = V_t - V_{fb} (V_c + V_{f\ell}) \quad (19)$$

The term $(V_t - V_a)$ can be substituted for V_{fb}, since fallback comprises the difference between the true and apparent crater profiles. It can be reduced to its in situ volume by using a bulking factor of 1.5, as an approximation. A small-scale test of surface detonations (Chew, Rooke, and Pitman 1968) actually measured both V_c and $V_{f\ell}$, the only such measurement known to the authors. For dry sand, it was found that $V_c < 0.02\ V_t$, but that $(V_c + V_{f\ell}) = 0.27\ V_t$. While the mechanisms of compaction and flowage are expected to vary considerably with differences in charge geometry and cratered

medium, their relation to true crater volume should be fairly constant for the ranges of conditions in this study; therefore, this assumption, along with the foregoing substitution, permits the following form of Equation 7:

$$\begin{aligned} V_e &= V_t - \frac{1}{1.5}(V_t - V_a) - 0.27\ V_t \\ &= 0.06\ V_t + 0.67\ V_a \end{aligned} \tag{20}$$

Also,

$$V_e = 0.73\ V_t - 0.67\ V_{fb} \tag{21}$$

Both Equations 20 and 21 have been used in the data tables.

101. The foregoing approaches have been used to calculate or estimate V_e and V_e/V_a wherever possible. These and V_e/V_a relations that could be found in the bibliographic literature then became the basis for estimation of ejecta quantities where only apparent crater volume was known. As a rule, the search was restricted to the charge size limitations of this study, since there are some indications that these relations change with increasing charge sizes. Where they could be found, measured relations were recorded for each test site. As would be expected, however, these data were often incomplete; and in some cases, there was lack of agreement between apparently similar soils at different test sites, so that the final selection of the V_e/V_a relation sometimes became a matter of judgment. Table 14 lists the relations derived from the literature search; these are discussed in general terms in the following paragraphs. Note that the table includes some small-scale studies in which charge weights are on the order of a fraction of a gram. These are viewed with somewhat the same suspicion as large-scale shots, where charges may be measured in tons. These small-scale studies were very carefully done, however, and the resulting relations are useful in filling the gaps in this study.

102. Note, in Table 14, that the silt/sand and clay/sand combinations at the several test sites differ considerably in the V_e/V_a relation. While relations at the two Fort Carson sites were quite consistent for a range of charge geometries, the tailored soils in the Fort Polk experiments varied rather widely. The WSMR dry silty sand showed even more variation, looking

more like the dry sand at the Eglin Air Force Base site. The WSMR data represent an average of three shots on which ejecta sampling was done; two such shots were discarded because the relations were obviously invalid. Although not entirely credible, the dry sand and dry silty sand data seem to show that a high V_e/V_a fraction does indeed exist for these conditions. It is speculated that this may be caused in part by elastic rebound, in which the bottom of the true crater "bounces" upward after passage of the compressional shock wave, leaving a true-crater mound in which in situ density has been reduced to the point that overall "compaction" may actually be negative. This event obviously reduces crater size and may lead to the unusually high V_e/V_a fraction.

103. It might be thought that an increase in moisture would reduce the V_e/V_a relation in soil, since it would be expected to increase both the plasticity and cohesion of the cratered medium; the former would be expected to result in a larger crater and the latter in a reduction in ejected material. The 20-ton FLAT TOP II and III shots seemed to show this. FLAT TOP III was identical to its predecessor except for soil moisture, which had approximately doubled, resulting in a crater that was larger by more than 50 percent, but in which the V_e/V_a relation was reduced nearly 40 percent (Ahlers and Miller 1966, Rooke and Davis 1966). While this holds true for some of the entries in Table 14, however, it is not seen consistently.

104. Finally, it should be noted that in some cases in the data tables (the BETS experiments), ejecta relations are based upon shot-to-shot moisture conditions and thus may seem to disagree with the relations in Table 14. In other cases, as for wet sand, the relations are the result of graphical interpolation of charge position. Table 14 gives recommended V_e/V_a fractions (after rejection of invalid measurements) and the basic statistics associated with each entry, where appropriate.

105. Figure 24 graphs V_e/V_a versus R_c for the bare-charge data of Table 14. All data are for sands and fine-grain soils, the main difference between cratered media being that of moisture content. The data scatter, which is especially prevalent in the drier soils, seems to preclude a more elaborate analysis. Based upon a visual fit, there appears to be a slight downward trend as the charge position is moved upward. For the surface to surface-tangent regime, the ratio V_e/V_a lies between 0.75 and 0.80. Judgment was used in applying these ratios and those of Table 14 to events for

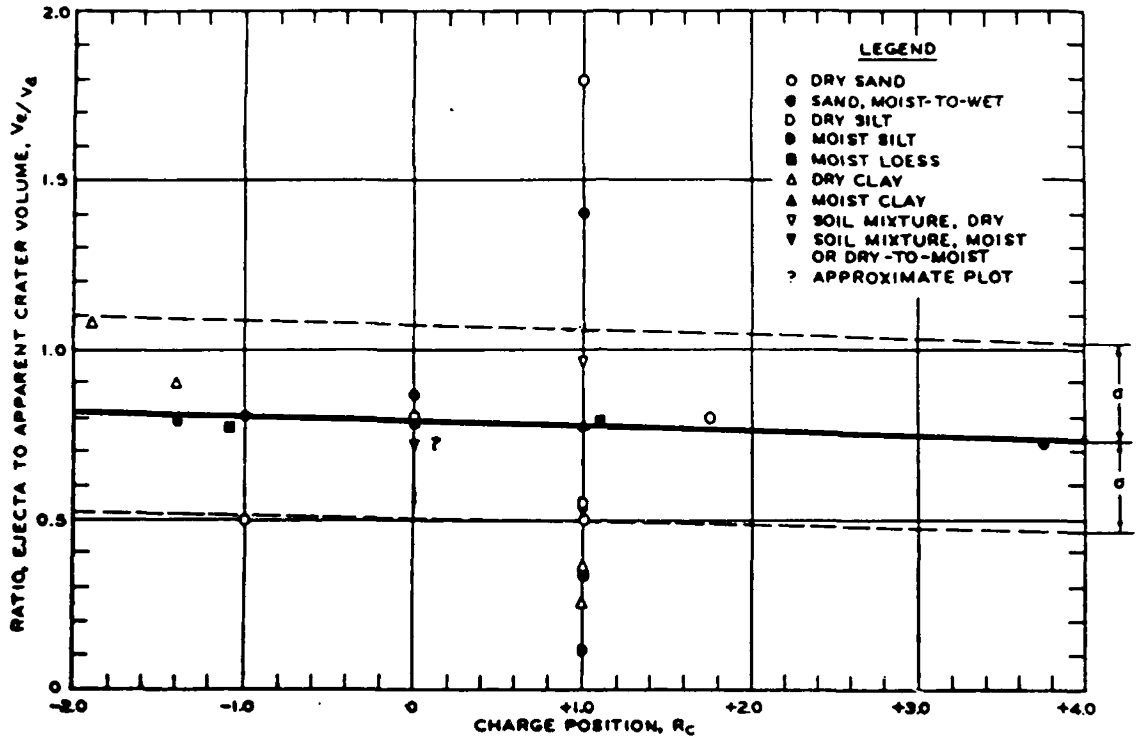

Figure 24. Graphical representation of ejecta volume/ apparent crater volume ratios of Table 14

which no ejecta measurements were available. In some cases, averages from different sites were used. Where used, selected ratios are shown under the "Ejec Cal" column.

Comparison of ejecta from cased and uncased charges

106. In Table 13, all projectile craters--static and live fire--were examined, and the resulting $V_e/V_a = 0.52$ was used to estimate ejecta quantities for the projectile craters of Table 9 except Shot T-27, for which a volumetric balance was available. However, Table 5 was not changed from its listing in the Phase I report where the V_e/V_a ratio equaled 0.53, a difference judged not to be significant in view of the uncertainty of results obtained in the Table 13 sample. This treatment minimizes the Shot T-27 results, which are considered low. Comparison of V_e/V_a ratios for cased and uncased charges indicates that the ratio for the former is only about two-thirds that of the latter.

Bare-Charge Simulation of Munitions

107. Although not one of the objectives of this study, it might be appropriate to discuss some of the findings that may prove helpful to researchers attempting to simulate cratering effects of munitions using uncased (bare) charges or attempting to correlate effects observed in past experiments. An example may serve to illustrate this point.

a. Suppose the DOT I study (Table 7) is reexamined to see how closely the B-series surface-tangent (ST) shots simulated the crater/ejecta effects of a 155-mm projectile fired in an ST geometry approximating live fire. Note that, in terms of TNT equivalence, charge weights are quite close: 6.46 kg for the bare charges versus 6.62 kg for the 155 mm. V_a from Rows 404-413 in Table 7 may, of course, be averaged, or an estimate from Figure 5 and its accompanying equation may be obtained:

$$V_a = 0.07\ W^{0.78} \tag{22}$$

Choosing the latter course tends to smooth out anomalous measurements such as the suspiciously large V_a of Rows 407. If it is decided to solve the equation, the following is obtained:

$$\begin{aligned} V_{a(bc)} &= 0.07\ (6.46)^{0.78} \\ &= 0.30\ m^3 \end{aligned} \tag{23}$$

where $V_{a(bc)}$ is the apparent crater volume for the bare charge. This could have been estimated directly from the graph. If V_a's had been averaged, 0.34 m^3 would have been obtained. Following a similar procedure with the data available on the 155-mm shell, the measurements in Tables 5 and 9 may be averaged, or any or all of Figures 22 and 23 and Table 11 can be referred to. If it is decided to use the "live plus selected static firings" and the $Y = AX^B$ fit, then

$$\begin{aligned} V_{a(mun)} &= 0.071W^{1.07} \\ &= 0.54\ m^3 \end{aligned} \tag{24}$$

where $V_{a(mun)}$ refers to apparent crater volume for the munition. Regarding ejecta, note that the best evidence now available indicates that the V_e/V_a ratio for projectile craters is significantly smaller than for bare charges. Table 14 or Figure 24 can be consulted for a bare-charge ratio and Table 13 for projectiles. Unfortunately, Table 14 does not

offer any clear-cut choices in this case; therefore, Figure 24 is resorted to, which gives an estimated bare-charge $V_e/V_a = 0.78$. Table 13 gives the projectile $V_e/V_a = 0.52$. Thus, without considering dust lofted by fragments impacting beyond the crater,

$$V_{e(bc)} = 0.78\ V_{a(bc)}$$

$$= 0.23\ m^3 \tag{25}$$

and

$$V_{e(mun)} = 0.52\ V_{a(mun)}$$

$$= 0.28\ m^3 \tag{26}$$

All things considered, it appears that a 155-mm shell fired in a fuze-quick configuration will produce a slightly larger quantity of ejecta than a DOT I, B-series ST charge.

b. Continuing with the example, if it is decided to design a follow-on experiment that will duplicate the DOT I B-series ST shots except for charge weight and will simulate the 155-mm conditions discussed above as closely as possible, it can be reasoned that more ejecta need to be produced from the bare-charge crater by a factor of $0.28/0.23 = 1.22$. Therefore, for the new bare charge Nc. 2(bc2),

$$1.22\ V_{e(bc)} = 0.78\ V_{a(bc2)}$$

$$1.22\ (0.23) = 0.78\ V_{a(bc2)}$$

$$V_{a(bc2)} = 0.36\ m^3 \tag{27}$$

To find the charge weight that will provide the required $V_{a(bc2)}$, use the graph of Figure 6 or solve

$$0.07\ W^{0.78} = 0.36$$

$$W = 8.13\ \text{kg (TNT equivalent)} \tag{28}$$

For C-4, with a 95-percent TNT equivalence in cratering, actual charge weight should be $(1/0.95)(8.13) = 8.54$ kg .

108. In the above example, the munitions crater is larger than the bare-charge crater, a result that is consistent with Figure 23 in the charge-weight range above 5 kg. However, it must be borne in mind that the munitions data base is small compared with that for bare charges and that a larger number of munitions observations under more varied conditions might lead to a different result. Thus, the significance of the differences in the example is

open to question. The reader is cautioned that the comparative procedure described above is primarily for illustrative purposes and should not be construed to imply that the differences are firmly established. Additional data, particularly additional artillery data, are needed for this purpose.

PART V: SUMMARY AND CONCLUSIONS

Crater Shape Factors

109. Shape factors have been established for both bare-charge and munitions craters for the calculation of crater volumes. While the former shows little deviation and can be used with confidence to calculate crater volumes, the latter varies widely with type of munition and test conditions. However, the mean value of the munitions shape factors is very close to that for bare charges, so that bare-charge factors may be used for munitions craters when pattern information is unavailable. These factors are 0.45 and 0.40 for apparent and true craters, respectively. Combining shape factors with π terms in the equation gives

$$V_a = 1.41\ r_a^2 d_a \tag{29}$$

and

$$V_a = 1.26\ r_t^2 d_t \tag{30}$$

VBSSFs

Apparent craters

110. A detailed analysis of the data base contained in Tables 1-9 shows that, for a general equation relating crater volume V to charge weight W,

$$V \propto W^n \tag{31}$$

where n is an exponent. The value of n should be 0.87 rather than the currently used 1.111. The actual apparent crater VBSSFs for various charge positions and soil types may be read from the graphs shown in Figures 10-13.

True craters

111. Regarding true craters, the exponent on charge weight is unity or 1.0. The true crater VBSSFs can be read from Figure 19 for various charge positions. In Figure 19, there is a tendency, though not well defined, for clay data, particularly moist-to-wet clay, to plot in the upper portion of the

data envelope, followed by silts, sands, and rocks, the final plotting near the bottom of the data envelope.

Ratio of True and Apparent Crater Volumes

112. The ratio of the true crater volume to the apparent crater volume (V_t/V_a) for various charge positions, without regard to soil type, is approximated by:

Charge Position Above or Below (-) Ground Surface, R_c	V_t/V_a
≥1.0	1.0
0	1.0 - 1.3
-1.0	1.3 - 1.7
-2.0	1.0 - 3.0

Effect of Vegetation on Crater Volume

113. Craters formed by explosions on bare ground are usually about 10 percent larger by volume than craters formed in a similar soil but with a grass cover that is less than 30 cm high. In such a case, it is presumed that coverage will range from 50 to 100 percent. Where the vegetative coverage is nearly 100 percent and consists of taller grasses, bushes, and undergrowth, as well as small trees, the crater in the vegetated areas will be 70 to 80 percent the size (by volume) of a crater over similar soil but without vegetation.

Effect of Soil Moisture on Crater Volume

114. Within the limitation of the data, it appears that soils that are wet, but not saturated to the point that slope failures occur around the crater wall, generally produce craters that are somewhat larger than dry or slightly moist soils. For wet sand, the linear dimensions of a crater are about 5 percent larger than for dry or slightly moist sand. For silts and clays, the linear dimensions of craters are typically about 10 percent larger

in wet soils than in those that are dry or slightly moist. These increases translate into a 15-percent volume increase for sand and a 25- to 30-percent increase for silts and clays when comparing dry or slightly moist with wet conditions. As to rock, no effect could be discerned for varying moisture content within the yield range of this study.

Cratering the HE Projectiles

115. Craters formed by HE projectiles detonated in live fire or in a geometry to simulate live fire differ markedly from comparable bare-charge craters in shape, but not in volume. As to comparisons between live and static fire of such projectiles, there appears to be little difference in overall crater size and shape.

Ejecta Assessment

116. Tables 1-9 contain 55 events in which there are sufficient data to permit direct calculation (by integration of areal-density measurements) of crater-ejecta volumes. This number, representing about 10.6 percent of the data base, is approximately evenly divided between bare-charge and munitions events. Another 16.5 percent of the data base is suitable for inference of ejecta quantities by means of volumetric balancing of the crater, all such balancing being based upon certain assumptions. Thus, in all, about 27 percent of the total data base has been used to derive ejecta/apparent-crater volume ratios (V_e/V_a) with which to estimate ejecta volumes for the remaining events on a shot-by-shot basis.

117. For bare charges, 24 V_e/V_a ratios were derived, representing most of the soil conditions encountered in the data base. Charge positions were predominantly surface to surface-tangent ($0 \le R_c \le 1.0$). While the data scatter seems to preclude rigorous analysis, its general trend indicates that $0.75 \lesssim V_e/V_a \lesssim 0.80$ in the near-surface regime, with a slight downward trend as charge position is moved from below-surface to above-surface. Thus, in bare-charge simulation of munitions, roughly three-fourths of the apparent crater volume is, on the average, lofted as ejecta.

118. In the case of munitions, only the 105- and 155-mm artillery projectile craters were usable for calculations of V_e/V_a, and these for only

three distinctly different soil conditions. Of these, a single live-fire event was available for the V_e/V_a calculation. Thus, in estimating crater-ejecta quantities for munitions, a limited number of charge and soil conditions necessarily served as the basis for the remaining events. The munitions ratios were lower than for bare charges, with $V_e/V_a = 0.52$, or about one standard deviation below the inspected mean shown in Figure 24. However, to this ratio should be added whatever surface material is dissociated and lofted by shell fragments impacting <u>outside</u> the crater; this quantity is not now known.

Bare-Charge Simulation of Munitions

119. Using the established data base and the crater/ejecta relations derived therefrom, a rational approach toward simulation of munitions with bare charges is demonstrated in paragraph 107. The illustration tends to substantiate field observations that bare charges produce smaller craters than do comparable munitions, but also shows that, for ejecta/dust production, this difference is narrowed by the higher V_e/V_a ratio exhibited by bare charges.

PART VI: RECOMMENDATIONS

120. In performing the analysis and in formulating the conclusions that were derived from the data base, one of the more glaring difficulties was the continuing problem of data scatter. Sources of data scatter, in the main, are believed to be: inconsistencies in crater measuring techniques, i.e., the definition of the crater profile (particularly the true crater profile); the inherent or subtle differences in reportedly similar soils at different sites, including differences in soil composition, moisture content, degree of saturation, etc.; differences in conversion factors regarding explosion yield among different types of explosives; and finally, the need to group similar shot-geometry ranges, since data for unique shot geometries were not available in sufficient quantity to permit confident analysis.

121. Wherever the degree of data scatter is found to be unacceptable, then additional testing--carefully designed and controlled--is recommended. However, the experimenter is advised that the most carefully controlled cratering experiments have shown a 10- to 15-percent scatter in linear dimensions, which translates to roughly 30-percent scatter in volume for a specific soil type, a specific charge position, and a single charge weight.

122. Additional, carefully controlled experiments are needed to better define quantities and distribution parameters relative to crater ejecta, especially those pertaining to both live and statically fired munitions and their comparisons with bare charges. Where possible, direct measurements of ejecta are preferred for this purpose, as by sampling, since this provides both ejecta quantity and distribution. The sampling techniques employed in the experiments reported herein are generally adequate, but would probably provide better results if sampling arrays were expanded. This technique does not, of course, apply to live fire, where the projectile detonation point cannot be known ahead of time; here only volumetric analysis is applicable. Nevertheless, estimates of ejecta volume V_e may be inferred from careful measurements of crater profiles. Using the volumetric relations discussed in paragraph 87 and assuming the volume of compaction that surrounds the true crater to be small, then

$$V_e \simeq V_a - V_{f\ell} \qquad (32)$$

where V_e is the ejecta volume, V_a is the apparent crater volume, and $V_{f\ell}$ is the volume of plastic flowage, which is the same as the volume of upthrusted (in situ) material in the crater lip, as shown in Figures 2 and 3.

123. In considering dust loadings resulting from artillery fire, both technical and tactical realities must be kept in mind. Shell fragments cause dust lofting outside fuze-quick craters in dry soils, as well as ejecta from inside the craters. Therefore, crater-ejecta volume alone will not account for the total amount of dust in such cases. In addition, airbursts are frequently used against soft targets, such as personnel, and these bursts may result in very significant dust loadings without the formation of <u>any</u> crater. Here again, additional field work is probably required to obtain realistic input to models. It may, however, be possible to obtain estimates of dust loadings from artillery fragments impacting the ground surface by reviewing and analyzing existing motion-picture photography of artillery fire that is available at the US Army Field Artillery School, Fort Sill, Okla. Prior to incurring the expense of additional field work, it is recommended that this approach at least be investigated.

124. Lastly, cratering effects of conventional aerial bombs also need additional study. This is another munition that is commonly used on the battlefield. General-purpose bombs are relatively thinly cased and employ different fuzing from artillery projectiles; hence, penetration and blast effects differ, also. Further, armor-piercing and semiarmor-piercing bombs have their own, separate characteristics that influence cratering. Some bomb-crater data are available from past studies, but their suitability for ejecta assessment is questionable. In this study, the upper limit of energy yield is sufficient to include bombs, but, for the reasons cited above, crater/ejecta predictions derived herein may not represent well the actual results for these munitions.

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KEY TO VEGETATION/CANOPY DESCRIPTIONS, TABLES 1-9

AZ - Short grasses, blue grama, Russian thistle, lamb's quarters, and/or prickly pear

BL - Black sand

BS - Bare soil

C - Covered

CG - Cut grass

DS - Dry sand (white)

G - *Gynerium Sagittatum*

GH&F - Grasses, herbs, and forbs

HG - High grass

LC - Low canopy

LG - Low grass

M - Morning glory

O - Other

P - *Panicum* sp (1 to 2 m tall)

S - Spider lily

U - Uncovered

WS - Wet sand

(50) - Indicates percent of ground covered (in this case 50 percent)

KEY TO COLUMN HEADINGS AND ENTRIES, TABLES 1-9

First Page of Each Table

Column No.	Heading	Meaning
1	Row	Defines row number
2	REF/SR	Reference/subreference
3	TEST P/S	Test program/series
4	A___OBS	Average of ___ observations
5	SHOT ID	Shot identification(s)
6	X COORD	X-coordinate
7	Y COORD	Y-coordinate
8	SOIL DES	Soil description
9	USCS	Unified Soil Classification System designation
10	SA, %	Percentage of sand in soil
11	SI, %	Percentage of silt in soil
12	CL, %	Percentage of clay in soil
13	MC, %	Moisture content, percent
14	DESA, %	Degree of saturation, percent
15	TYPE CH	Type explosive (charge)
16	CH WT, kg	Charge weight, W , kilograms
17	F TNT, kg	Equivalent charge weight, TNT, kilograms
18	TM C/M	Type munition, caliber/model
19	MO D/A	Munition orientation, description/angle Notation used in column entries: S - Surface (half-buried) geometry ST - Surface-tangent STB - Surface-tangent-below, or buried one projectile length 1/3BUR90 - Projectile buried one-third of its length and at 90-deg angle from horizontal 1/3BUR45 - Projectile buried one-third of its length and at 45-deg angle from horizontal
20	H/DOB, R	Charge/munition height or depth of burst in equivalent TNT charge radii

KEY TO COLUMN HEADINGS AND ENTRIES, TABLES 1-9

Continuation Sheet of Each Table

Column No.	Heading	Meaning
1	Row	Defines row number
2	Shot ID	Shot identification(s)
3	r_a, m	Apparent crater radius, metres
4	d_a, m	Apparent crater depth, metres
5	V_a, m^3	Apparent crater volume, cubic metres
6	r_t, m	True crater radius, metres
7	d_t, m	True crater depth, metres
8	V_t, m^3	True crater volume, cubic metres
9	V_a' m^3/W_s	Apparent crater volume/charge weight to the 0.87 power ($V_a/W^{0.87}$)
10	V_a/W_n	Apparent crater volume/charge weight to the 1.111 power ($V_a/W^{1.111}$)
11	V_t' m^3/kg	True crater volume/charge weight, m^3/kg
12	V_t/Wn	True crater volume/charge weight to the 1.111 power ($m^3/kg^{1.111}$)
13	V_e, m^3	Volume of ejecta, cubic metres
14	W_e, kg	Weight of ejecta, kilograms
15	Ejec Cal	Basis of ejecta volume calculations--equation based on sampling, volumetric balance, or ejecta-apparent crater volume ratio
16	D C OBS	Dust cloud observation, m^2/sec. Maximum target area obscured at t seconds after detonation.
17	K_s	Crater shape factor (apparent or true crater)
18	V/C Des	Vegetation/canopy description

KEY TO SOIL DESCRIPTIONS, TABLES 1-9

Soil Description Nomenclature	Meaning
DDALLUV	Dry desert alluvium
DTMSand	Dry-to-moist sand
ICl	Inorganic clay
ICl-SaM	Inorganic clay-sand mixture
ISiClSi	Inorganic silt--clayey silt
Kaolin	Fat clay
M-Loess	Moist loess
MSaSilt	Moist sandy silt
MSaSiCl	Moist sandy silty clay
MSiClay (MSiCl)	Moist silty clay
MSiSand	Moist silty sand
PGSa	Poorly graded sand
PUMSAND	Pumice sand
Rock B-G	Rock, basalt, or granite
SANDST	Sandstone
SaCl	Sandy clay
SaCl,P	Sandy clay, plastic
SaClSi	Sandy clayey silt
SaSi	Sandy silt
SaSiCl	Sandy silty clay
SH-T-FG	Shale, tuff, or frozen ground
SiCl	Silty clay
SiSand (SiSa)	Silty sand
SiSa Mix	Mixture of silt and sand
UNISAND	Uniform sand

Table 1

Cratering Data from the WES Compendium

DRY CLAY

ROW	REF/SR	TEST P/S	A OBS	SHOT ID	X COORD	Y COORD	SOIL DES	USCS	SA.%	SI.%	CL.%	MC.%	DESA.%	TYPE CH	CH WT.kg	E TNT.kg	TN C/M	MO D/A	H/DOB.R
1	40/44	HOLE	1	111			DRY CLAY	CL						TNT	116.00	118.00			1.90
2	40/46	HOLE	1	104			DRY CLAY	CL						TNT	116.00	118.00			1.00
3	40/46	HOLE	1	107			DRY CLAY	CL						TNT	116.00	118.00			0.00
4	40/60	UETP	1	303			DRY CLAY	CL						TNT	116.00	116.00			-1.40
5	40/46	HOLE	1	106			DRY CLAY	CL						TNT	116.00	118.00			-1.80

MOIST CLAY

ROW	REF/SR	TEST P/S	A OBS	SHOT ID	X COORD	Y COORD	SOIL DES	USCS	SA.%	SI.%	CL.%	MC.%	DESA.%	TYPE CH	CH WT.kg	E TNT.kg	TN C/M	MO D/A	H/DOB.R
6	40/11	CESBC	1	57			MOIST CLAY	CL						C4	0.45	0.43			0.00
7	40/24	ICSRC	1	6			MOIST CLAY	CL						TNT	11.30	11.30			0.00

WET CLAY

ROW	REF/SR	TEST P/S	A OBS	SHOT ID	X COORD	Y COORD	SOIL DES	USCS	SA.%	SI.%	CL.%	MC.%	DESA.%	TYPE CH	CH WT.kg	E TNT.kg	TN C/M	MO D/A	H/DOB.R
8	40/46	HOLE	1	313			WET CLAY	CL						TNT	116.00	118.00			1.00
9	40/23	ICSMM-15	1	15			WET CLAY	CL						TNT	11.30	11.30			0.00
10	40/23	ICSMM-16	1	1A			WET CLAY	CL						TNT	22.70	22.70			0.00
11	40/23	ICSMM-17	1	2A			WET CLAY	CL						TNT	22.70	22.70			0.00
12	40/30	EUE	1	6-62			WET CLAY	CL						TNT	29.00	29.00			0.00

MOIST LOESS

ROW	REF/SR	TEST P/S	A OBS	SHOT ID	X COORD	Y COORD	SOIL DES	USCS	SA.%	SI.%	CL.%	MC.%	DESA.%	TYPE CH	CH WT.kg	E TNT.kg	TN C/M	MO D/A	H/DOB.R
13	40/5	AV II	1	01			M-LOESS	CL	10*	40*	50*	10*	20*	TNT	116.00	118.00			1.00
14	40/6	ANC	1	1A			M-LOESS	CL	10*	40*	50*	10*	20*	AN	22.70	23.40			1.00
15	40/6	ANC	1	2A			M-LOESS	CL	10*	40*	50*	10*	20*	AN	22.70	23.40			1.00
16	40/6	ANC	1	3A			M-LOESS	CL	10*	40*	50*	10*	20*	TNT	22.70	22.70			1.00
17	40/6	ANC	1	4A			M-LOESS	CL	10*	40*	50*	10*	20*	TNT	22.70	22.70			1.00
18	40/6	ANC	1	5A			M-LOESS	CL	10*	40*	50*	10*	20*	AN	22.70	23.40			1.20
19	40/6	ANC	1	6A			M-LOESS	CL	10*	40*	50*	10*	20*	AN	22.70	23.40			1.20
20	40/11	CESBC	1	1B			M-LOESS	CL	10*	40*	50*	10*	20*	C4	0.45	0.43			0.00
21	40/11	CESBC	1	2B			M-LOESS	CL	10*	40*	50*	10*	20*	C4	0.45	0.43			0.00
22	40/5	AV II	1	02B			M-LOESS	CL	10*	40*	50*	10*	20*	TNT	116.00	118.00			0.00
23	40/5	AV III	1	01A			M-LOESS	CL	10*	40*	50*	10*	20*	TNT	29.00	29.00			0.00
24	40/5	AV III	1	01B			M-LOESS	CL	10*	40*	50*	10*	20*	TNT	29.00	29.00			0.00
25	40/5	AV III	1	01C			M-LOESS	CL	10*	40*	50*	10*	20*	TNT	29.00	29.00			0.00
26	40/5	AV III	1	01D			M-LOESS	CL	10*	40*	50*	10*	20*	TNT	29.00	29.00			0.00
27	40/6	ANC	1	1B			M-LOESS	CL	10*	40*	50*	10*	20*	AN	22.70	23.40			0.00
28	40/6	ANC	1	2B			M-LOESS	CL	10*	40*	50*	10*	20*	AN	22.70	23.40			0.00
29	40/6	ANC	1	3B			M-LOESS	CL	10*	40*	50*	10*	20*	AN	22.70	23.40			0.00
30	40/6	ANC	1	4B			M-LOESS	CL	10*	40*	50*	10*	20*	TNT	22.70	22.70			0.00
31	40/6	ANC	1	5B			M-LOESS	CL	10*	40*	50*	10*	20*	AN	22.70	23.40			0.00
32	40/5	AV II	1	03			M-LOESS	CL	10*	40*	50*	10*	20*	TNT	116.00	118.00			-1.00
33	40/6	ANC	1	1C			M-LOESS	CL	10*	40*	50*	10*	20*	AN	22.70	23.40			-1.00
34	40/6	ANC	1	2C			M-LOESS	CL	10*	40*	50*	10*	20*	AN	22.70	23.40			-1.00
35	40/6	ANC	1	3C			M-LOESS	CL	10*	40*	50*	10*	20*	TNT	22.70	22.70			-1.00
36	40/6	ANC	1	4C			M-LOESS	CL	10*	40*	50*	10*	20*	AN	22.70	23.40			-1.20
37	40/6	ANC	1	5C			M-LOESS	CL	10*	40*	50*	10*	20*	AN	22.70	23.40			-1.20

(Continued)

(Sheet 1 of 10)

Table 1 (Continued)

ROW	SHOT ID	ra,m	da,m	Va,m3	rt,m	dt,m	Vt,m3	Va'm3/We	Va/Wn	Vt'm3/kg	Vt/Wn	Ve,m3	We,kg	Ejec Cal	D C Obs	Ke	V/C Des
									DRY CLAY								
1	111			1.64			21.0	2.47E-2	7.83E-3	1.81E-1	1.07E-1	1.64		ve=1.0va			
2	104	1.65	0.48	1.70			23.2	2.73E-2	8.65E-3	2.00E-1	1.18E-1	1.70		ve=1.0va			
3	107	2.01	1.19	6.57			56.4	1.06E-1	3.34E-2	4.88E-1	2.87E-1	6.57		ve=1.0va			
4	303	2.74	1.66	17.0	4.11	2.13	65.2	2.73E-1	8.65E-2	5.62E-1	3.32E-1	16.3		ve=0.67va+0.06vt			
5	106	2.77	1.69	15.2			101	2.43E-1	7.73E-2	8.71E-1	5.14E-1	16.2		ve=0.67va+0.06vt			
									MOIST CLAY								
6	57	0.46	0.16	6.07E-2	0.46	0.27	6.7E-2	1.16E-1	1.45E-1	1.32E-1	1.45E-1	4.18E-2		ve=0.67va+0.06vt			
7	8	1.16	0.84	9.40E-1	1.37	0.76	1.64	1.14E+0	6.36E-2	1.45E-1	1.11E-1	7.28E-1		ve=0.67va+0.06vt			
									WET CLAY								
8	313	1.86	1.04	4.62				7.38E-2	2.35E-2			3.23		ve=0.7va			
9	15	1.74	1.19	6.15				7.46E-1	4.16E-1			4.30		ve=0.7va			
10	1A	2.20	1.52	13.71				9.08E-1	4.27E-1			9.60		ve=0.7va			
11	2A	2.32	1.52	13.0				8.60E-1	4.05E-1			9.10		ve=0.7va			
12	8-62	1.04															
									MOIST LOESS								
13	01	1.59	0.24	2.76E-1	1.25	0.76	2.07	4.42E-3	1.40E-3	1.76E-2	1.05E-2	3.09E-1		ve=0.67va+0.06vt			
14	1A	0.97	0.55	7.32E-1*	0.97	0.55	7.32E-1*	4.72E-2*	2.20E-2*	2.76E-2*	1.96E-2*	5.29E-1*		ve=0.67va+0.06vt		0.45/0.40	
15	2A	0.82	0.58	5.51E-1*	0.82	0.58	5.51E-1*	3.54E-2*	1.66E-2*	2.09E-2*	1.48E-2*	3.99E-1*		ve=0.67va+0.06vt		0.45/0.40	
16	3A	1.04	0.84	9.79E-1*	1.10	0.70	1.09*	6.47E-2*	3.05E-2*	4.67E-2*	3.30E-2*	7.20E-1*		ve=0.67va+0.06vt		0.45/0.40	
17	4A	0.98	0.64	8.89E-1*	1.13	0.67	1.09*	5.75E-2*	2.71E-2*	4.79E-2*	3.38E-2*	6.47E-1*		ve=0.67va+0.06vt		0.45/0.40	
18	5A	0.82	0.48	4.37E-1*	0.85	0.55	5.00E-1*	2.82E-2*	1.32E-2*	2.14E-2*	1.51E-2*	3.23E-1*		ve=0.67va+0.06vt		0.45/0.40	
19	6A	0.85	0.43	4.39E-1*	1.04	0.49	6.68E-1*	2.83E-2*	1.32E-2*	2.85E-2*	2.01E-2*	3.34E-1*		ve=0.67va+0.06vt		0.45/0.40	
20	19	0.37	0.16	3.00E-2	0.37	0.24	3.00E-2	8.24E-2	7.84E-2	8.98E-2	7.64E-2	2.19E-2		ve=0.67va+0.06vt			
21	25	0.37	0.15	3.00E-2	0.43	0.24	3.00E-2	8.24E-2	7.64E-2	8.98E-2	7.64E-2	2.19E-2		ve=0.67va+0.06vt			
22	029	1.65	0.73	2.84				4.23E-2	1.34E-2			2.08		ve=0.78va			
23	01A	1.04	0.49	8.80E-1	1.29	0.79	1.70	3.83E-2	1.81E-2	5.88E-2	4.03E-2	5.58E-1		ve=0.67va+0.06vt			
24	01B	1.04	0.55	7.40E-1	1.16	0.79	1.44	3.95E-2	1.76E-2	5.00E-2	3.44E-2	5.83E-1		ve=0.67va+0.06vt			
25	01C	1.01	0.55	6.50E-1	1.19	0.85	1.56	3.47E-2	1.54E-2	5.38E-2	3.70E-2	5.29E-1		ve=0.67va+0.06vt			
26	01D	1.07	0.59	7.90E-1	1.19	0.79	1.44	4.21E-2	1.87E-2	4.97E-2	3.42E-2	6.16E-1		ve=0.67va+0.06vt			
27	1B	1.31	0.82	1.99*				1.28E-1*	5.99E-2*			1.55*		ve=0.78va		0.45/-	
28	2B	1.31	0.85	2.06*	1.68	1.04	3.69*	1.33E-1*	6.20E-2*	1.58E-1*	1.11E-1*	1.60*		ve=0.67va+0.06vt		0.45/0.40	
29	3B	1.56	0.85	2.89*	1.89	1.04	4.67*	1.87E-1*	8.70E-2*	2.00E-1*	1.41E-1*	2.22*		ve=0.67va+0.06vt		0.45/0.40	
30	4B	1.34	0.81	2.31*	1.95	0.98	4.69*	1.53E-1*	7.20E-2*	2.09E-1*	1.41E-1*	1.83*		ve=0.67va+0.06vt		0.45/0.40	
31	5B	1.40	0.88	2.44*	1.68	1.07	3.80*	1.57E-1*	7.35E-2*	1.62E-1*	1.14E-1*	1.86*		ve=0.67va+0.06vt		0.45/0.40	
32	03	2.04	1.04	8.86	2.53	1.59	10.97	1.06E-1*	3.39E-2*	8.46E-2*	5.58E-2*	6.12		ve=0.67va+0.06vt			
33	1C	1.86	1.10	5.38*	2.26	1.37	8.79*	3.47E-1*	1.62E-1*	3.76E-1*	2.65E-1*	4.13*		ve=0.67va+0.06vt		0.45/0.40	
34	2C	1.89	1.13	5.71*	2.04	1.31	6.86*	3.68E-1*	1.72E-1*	2.93E-1*	2.06E-1*	4.24*		ve=0.67va+0.06vt		0.45/0.40	
35	3C	1.71	1.16	4.80*	1.95	1.29	6.12*	3.17E-1*	1.50E-1*	2.70E-1*	1.91E-1*	3.68*		ve=0.67va+0.06vt		0.45/0.40	
36	4C	1.83	1.04	4.92*	1.93	1.46	6.14*	3.16E-1*	1.49E-1*	2.62E-1*	1.85E-1*	3.66*		ve=0.67va+0.06vt		0.45/0.40	
37	5C	1.92	1.28	6.87*	2.29	1.52	9.76*	4.29E-1*	2.01E-1*	4.17E-1*	2.94E-1*	5.05*		ve=0.67va+0.06vt		0.45/0.40	

(Continued)

(Sheet 2 of 10)

Table 1 (Continued)

ROW	REF/GR	TEST P/S	A OBS	SHOT ID	X COORD	Y COORD	SOIL DES	USCS	SA,%	SI,%	CL,%	MC,%	DESA,%	TYPE CH	CH WT,kg	E TNT,kg	TM C/M	MD D/A	H/DOB,R
38	40/16	SEB	1	01			SiCl	CL*	10*	25*	65*	5-10*	10-20*	TNT	3.83	3.83			1.00
39	40/16	SEB	1	02			SiCl	CL*	10*	25*	65*	5-10*	10-20*	TNT	3.83	3.83			1.00
40	40/16	SEB	1	03			SiCl	CL*	10*	25*	65*	5-10*	10-20*	TNT	3.83	3.83			1.00
41	40/16	SEB	1	04			SiCl	CL*	10*	25*	65*	5-10*	10-20*	TNT	3.83	3.83			1.00
42	40/16	SEB	1	05			SiCl	CL*	10*	25*	65*	5-10*	10-20*	TNT	3.83	3.83			1.00
43	40/16	SEB	1	06			SiCl	CL*	10*	25*	65*	5-10*	10-20*	TNT	3.83	3.83			1.00
44	40/16	SEB	1	07			SiCl	CL*	10*	25*	65*	5-10*	10-20*	TNT	3.83	3.83			1.00
45	40/16	SEB	1	08			SiCl	CL*	10*	25*	65*	5-10*	10-20*	TNT	3.83	3.83			1.00
46	40/16	SEB	1	09			SiCl	CL*	10*	25*	65*	5-10*	10-20*	TNT	3.83	3.83			1.00
47	40/16	SEB	1	10			SiCl	CL*	10*	25*	65*	5-10*	10-20*	TNT	3.83	3.83			1.00
48	40/16	SEB	1	41			SiCl	CL*	10*	25*	65*	5-10*	10-20*	TNT	27.20	27.20			1.00
49	40/16	SEB	1	42			SiCl	CL*	10*	25*	65*	5-10*	10-20*	TNT	27.20	27.20			1.00
50	40/16	SEB	1	43			SiCl	CL*	10*	25*	65*	5-10*	10-20*	TNT	27.20	27.20			1.00
51	40/16	SEB	1	44			SiCl	CL*	10*	25*	65*	5-10*	10-20*	TNT	27.20	27.20			1.00
52	40/16	SEB	1	45			SiCl	CL*	10*	25*	65*	5-10*	10-20*	TNT	27.20	27.20			1.00
53	40/16	SEB	1	46			SiCl	CL*	10*	25*	65*	5-10*	10-20*	TNT	27.20	27.20			1.00
54	40/16	SEB	1	47			SiCl	CL*	10*	25*	65*	5-10*	10-20*	TNT	27.20	27.20			1.00
55	40/16	SEB	1	48			SiCl	CL*	10*	25*	65*	5-10*	10-20*	TNT	27.20	27.20			1.00
56	40/16	SEB	1	49			SiCl	CL*	10*	25*	65*	5-10*	10-20*	TNT	27.20	27.20			1.00
57	40/16	SEB	1	50			SiCl	CL*	10*	25*	65*	5-10*	10-20*	TNT	27.20	27.20			1.00
58	40/16	SEB	1	70			SiCl	CL*	10*	25*	65*	5-10*	10-20*	TNT	27.20	27.20			1.00
59	40/16	SEB	1	71			SiCl	CL*	10*	25*	65*	5-10*	10-20*	TNT	27.20	27.20			1.00
60	40/16	SEB	1	73			SiCl	CL*	10*	25*	65*	5-10*	10-20*	TNT	27.20	27.20			1.00
61	40/16	SEB	1	69			SiCl	CL*	10*	25*	65*	5-10*	10-20*	TNT	474.00	474.00			1.00
62	40/16	SEB	1	32			SiCl	CL*	10*	25*	65*	5-10*	10-20*	TNT	13.60	13.60			0.40
63	40/16	SEB	1	33			SiCl	CL*	10*	25*	65*	5-10*	10-20*	TNT	13.60	13.60			0.40
64	40/16	SEB	1	34			SiCl	CL*	10*	25*	65*	5-10*	10-20*	TNT	13.60	13.60			0.40
65	40/16	SEB	1	35			SiCl	CL*	10*	25*	65*	5-10*	10-20*	TNT	13.60	13.60			0.40
66	40/16	SEB	1	36			SiCl	CL*	10*	25*	65*	5-10*	10-20*	TNT	13.60	13.60			0.40
67	40/16	SEB	1	37			SiCl	CL*	10*	25*	65*	5-10*	10-20*	TNT	13.60	13.60			0.40
68	40/16	SEB	1	38			SiCl	CL*	10*	25*	65*	5-10*	10-20*	TNT	13.60	13.60			0.40
69	40/16	SEB	1	39			SiCl	CL*	10*	25*	65*	5-10*	10-20*	TNT	13.60	13.60			0.40
70	40/16	SEB	1	40			SiCl	CL*	10*	25*	65*	5-10*	10-20*	TNT	13.60	13.60			0.40
71	40/16	SEB	1	21			SiCl	CL*	10*	25*	65*	5-10*	10-20*	TNT	3.83	3.83			0.50
72	40/16	SEB	1	22			SiCl	CL*	10*	25*	65*	5-10*	10-20*	TNT	3.83	3.83			0.50
73	40/16	SEB	1	23			SiCl	CL*	10*	25*	65*	5-10*	10-20*	TNT	3.83	3.83			0.50
74	40/16	SEB	1	25			SiCl	CL*	10*	25*	65*	5-10*	10-20*	TNT	3.83	3.83			0.50
75	40/16	SEB	1	24			SiCl	CL*	10*	25*	65*	5-10*	10-20*	TNT	3.83	3.83			0.50
76	40/16	SEB	1	26			SiCl	CL*	10*	25*	65*	5-10*	10-20*	TNT	3.83	3.83			0.50
77	40/16	SEB	1	27			SiCl	CL*	10*	25*	65*	5-10*	10-20*	TNT	3.83	3.83			0.50
78	40/16	SEB	1	28			SiCl	CL*	10*	25*	65*	5-10*	10-20*	TNT	3.83	3.83			0.50
79	40/16	SEB	1	29			SiCl	CL*	10*	25*	65*	5-10*	10-20*	TNT	3.83	3.83			0.50
80	40/16	SEB	1	30			SiCl	CL*	10*	25*	65*	5-10*	10-20*	TNT	3.83	3.83			0.50
81	40	DP	1	8			SiCl	CL*	10*	25*	65*	5-10*	10-20*	TNT	90700.00	90700.00			1.00
82	40	DP	1	8A			SiCl	CL*	10*	25*	65*	5-10*	10-20*	TNT	18100.00	18100.00			1.00
83	40	PF	1	PF			ClSi	ML*	10*	55*	35*	10-15*	15-25*	TNT	454000.00	454000.00			1.00
84	40		1	DIAL P			SiCl	CL*	10*	25*	65*	5-10*	10-20*	TNT	454000.00	454000.00			1.00
85	40/16	SEB	1	11			SiCl	CL*	10*	25*	65*	5-10*	10-20*	TNT	3.83	3.83			0.00
86	40/16	SEB	1	12			SiCl	CL*	10*	25*	65*	5-10*	10-20*	TNT	3.83	3.83			0.00
87	40/16	SEB	1	13			SiCl	CL*	10*	25*	65*	5-10*	10-20*	TNT	3.83	3.83			0.00
88	40/16	SEB	1	14			SiCl	CL*	10*	25*	65*	5-10*	10-20*	TNT	3.83	3.83			0.00
89	40/16	SEB	1	15			SiCl	CL*	10*	25*	65*	5-10*	10-20*	TNT	3.83	3.83			0.00
90	40/16	SEB	1	16			SiCl	CL*	10*	25*	65*	5-10*	10-20*	TNT	3.83	3.83			0.00

(Continued)

Table 1 (Continued)

ROW	SHOT ID	ra,m	da,m	Va,m3	rt,m	dt,m	Vt,m3	Va'm3/Wa	Va/Wn	Vt'm3/kg	Vt/Wn	Ve,m3	We,kg	Ejec Cal	D C Obs	Ke	V/C Des
38	01	0.24	0.21	1.70E-2*				5.83E-3*	4.20E-3*			1.25E-2*		ve=0.7va		0.45/-	
39	02	0.24	0.21	1.70E-2*				5.83E-3*	4.20E-3*			1.25E-2*		ve=0.7va		0.45/-	
40	03	0.24	0.21	1.70E-2*				5.83E-3*	4.20E-3*			1.25E-2*		ve=0.7va		0.45/-	
41	04	0.24	0.24	2.08E-2*				6.66E-3*	4.80E-3*			1.44E-2*		ve=0.7va		0.45/-	
42	05	0.24	0.21	1.70E-2*				5.83E-3*	4.27E-3*			1.25E-2*		ve=0.7va		0.45/-	
43	06	0.24	0.21	1.70E-2*				5.83E-3*	4.27E-3*			1.25E-2*		ve=0.7va		0.45/-	
44	07	0.24	0.18	1.54E-2*				5.01E-3*	3.60E-3*			1.08E-2*		ve=0.7va		0.45/-	
45	08	0.24	0.08	7.00E-3*				2.40E-3*	1.83E-3*			5.38E-3*		ve=0.7va		0.45/-	
46	09	0.24	0.15	1.28E-2*				4.17E-3*	3.08E-3*			8.96E-3*		ve=0.7va		0.45/-	
47	10	0.21	0.15	9.75E-3*				3.18E-3*	2.33E-3*			6.82E-3*		ve=0.7va		0.45/-	
48	41	0.73	0.43	3.24E-1*				1.83E-2*	8.26E-3*			2.27E-1*		ve=0.7va		0.45/-	
49	42	0.70	0.46	3.18E-1*				1.80E-2*	8.13E-3*			2.23E-1*		ve=0.7va		0.45/-	
50	43	0.73	0.43	3.24E-1*				1.83E-2*	8.26E-3*			2.27E-1*		ve=0.7va		0.45/-	
51	44	0.67	0.49	3.11E-1*				1.76E-2*	7.92E-3*			2.18E-1*		ve=0.7va		0.45/-	
52	45	0.73	0.49	3.70E-1*				2.09E-2*	9.43E-3*			2.59E-1*		ve=0.7va		0.45/-	
53	46	0.61	0.40	2.10E-1*				1.19E-2*	5.35E-3*			1.47E-1*		ve=0.7va		0.45/-	
54	47	0.58	0.46	2.17E-1*				1.23E-2*	5.53E-3*			1.52E-1*		ve=0.7va		0.45/-	
55	48	0.55	0.55	2.34E-1*				1.32E-2*	5.96E-3*			1.64E-1*		ve=0.7va		0.45/-	
56	49	0.58	0.52	2.46E-1*				1.39E-2*	6.27E-3*			1.72E-1*		ve=0.7va		0.45/-	
57	50	0.58	0.46	2.19E-1*				1.24E-2*	5.58E-3*			1.53E-1*		ve=0.7va		0.45/-	
58	70	0.61	0.52	2.74E-1*				1.55E-2*	6.98E-3*			1.92E-1*		ve=0.7va		0.45/-	
59	71	0.58	0.58	2.76E-1*				1.56E-2*	7.03E-3*			1.93E-1*		ve=0.7va		0.45/-	
60	73	0.61	0.55	2.89E-1*				1.63E-2*	7.36E-3*			2.02E-1*		ve=0.7va		0.45/-	
61	69	1.83	0.52	2.46*				1.18E-2*	2.82E-3*			1.72*		ve=0.7va		0.45/-	
62	32	0.49	0.67	2.27E-1*				2.34E-2*	1.26E-2*			1.59E-1*		ve=0.7va		0.45/-	
63	33	0.61	0.61	3.21E-1*				3.31E-2*	1.77E-2*			2.25E-1*		ve=0.7va		0.45/-	
64	34	0.49	0.82	2.79E-1*				2.88E-2*	1.53E-2*			1.95E-1*		ve=0.7va		0.45/-	
65	35	0.46	0.84	2.17E-1*				2.25E-2*	1.19E-2*			1.52E-1*		ve=0.7va		0.45/-	
66	36	0.46	0.64	1.91E-1*				1.97E-2*	1.05E-2*			1.34E-1*		ve=0.7va		0.45/-	
67	37	0.46	0.70	2.38E-1*				2.46E-2*	1.31E-2*			1.67E-1*		ve=0.7va		0.45/-	
68	38	0.46	0.81	2.72E-1*				2.81E-2*	1.50E-2*			1.90E-1*		ve=0.7va		0.45/-	
69	39	0.46	0.84	2.17E-1*				2.25E-2*	1.19E-2*			1.52E-1*		ve=0.7va		0.45/-	
70	40	0.46	0.79	2.68E-1*				2.77E-2*	1.47E-2*			1.88E-1*		ve=0.7va		0.45/-	
71	21	0.30	0.46	5.85E-2*				1.90E-2*	1.40E-2*			4.10E-2*		ve=0.7va		0.45/-	
72	22	0.31	0.46	6.66E-2*				2.16E-2*	1.58E-2*			4.66E-2*		ve=0.7va		0.45/-	
73	23	0.27	0.52	5.38E-2*				1.75E-2*	1.28E-2*			3.76E-2*		ve=0.7va		0.45/-	
74	25	0.27	0.46	4.74E-2*				1.55E-2*	1.13E-2*			3.32E-2*		ve=0.7va		0.45/-	
75	24	0.27	0.49	5.06E-2*				1.64E-2*	1.21E-2*			3.54E-2*		ve=0.7va		0.45/-	
76	26	0.21	0.37	2.31E-2*				7.52E-3*	5.52E-3*			1.62E-2*		ve=0.7va		0.45/-	
77	27	0.18	0.40	1.83E-2*				5.96E-3*	4.37E-3*			1.28E-2*		ve=0.7va		0.45/-	
78	28	0.21	0.43	2.68E-2*				8.73E-3*	6.40E-3*			1.88E-2*		ve=0.7va		0.45/-	
79	29	0.24	0.46	3.99E-2*				1.30E-2*	9.53E-3*			2.79E-2*		ve=0.7va		0.45/-	
80	30	0.24	0.46	3.75E-2*				1.22E-2*	8.95E-3*			2.62E-2*		ve=0.7va		0.45/-	
81	6	13.00	4.50	1.08E3 *				5.25E-2*	3.35E-3*							0.45/-	
82	6A	7.80	3.30	2.70E2 *				5.33E-2*	5.02E-3*							0.45/-	
83	PF	31.00	5.00	8.79E3 *				9.16E-2*	3.52E-3*							0.45/-	
84	DIAL P	29.00	4.00	4.70E3 *	47.30	4.57	16300.	6.71E-2*	2.47E-3*	3.59E-2	8.46E-3					0.45/-	
85	11	0.34	0.27	4.41E-2*				1.43E-2*	1.05E-2*			3.09E-2*		ve=0.7va		0.45/-	
86	12	0.37	0.18	3.48E-2*				1.13E-2*	8.31E-3*			2.44E-2*		ve=0.7va		0.45/-	
87	13	0.34	0.24	3.92E-2*				1.28E-2*	9.36E-3*			2.74E-2*		ve=0.7va		0.45/-	
88	14	0.37	0.21	4.07E-2*				1.32E-2*	9.72E-3*			2.85E-2*		ve=0.7va		0.45/-	
89	15	0.37	0.27	5.23E-2*				1.70E-2*	1.25E-2*			3.66E-2*		ve=0.7va		0.45/-	
90	16	0.37	0.34	6.58E-2*				2.14E-2*	1.57E-2*			4.61E-2*		ve=0.7va		0.45/-	

(Continued)

Table 1 (Continued)

ROW	REF/SR	TEST P/S	A OBS	SHOT ID	X COORD	Y COORD	SOIL DES	USCS	SA,%	SI,%	CL,%	MC,%	DESA,%	TYPE CH	CH WT,kg	E TNT,kg	TN C/M	MD D/A	H/DOB,R
91	40/18	SES	1	17			SICl	CL*	10*	25*	65*	5-10*	10-20*	TNT	3.83	3.83			0.00
92	40/18	SES	1	18			SICl	CL*	10*	25*	65*	5-10*	10-20*	TNT	3.83	3.83			0.00
93	40/18	SES	1	19			SICl	CL*	10*	25*	65*	5-10*	10-20*	TNT	3.83	3.83			0.00
94	40/18	SES	1	20			SICl	CL*	10*	25*	65*	5-10*	10-20*	TNT	3.83	3.83			0.00
95	40/18	SES	1	51			SICl	CL*	10*	25*	65*	5-10*	10-20*	TNT	27.20	27.20			0.00
96	40/18	SES	1	52			SICl	CL*	10*	25*	65*	5-10*	10-20*	TNT	27.20	27.20			0.00
97	40/18	SES	1	53			SICl	CL*	10*	25*	65*	5-10*	10-20*	TNT	27.20	27.20			0.00
98	40/18	SES	1	54			SICl	CL*	10*	25*	65*	5-10*	10-20*	TNT	27.20	27.20			0.00
99	40/18	SES	1	55			SICl	CL*	10*	25*	65*	5-10*	10-20*	TNT	27.20	27.20			0.00
100	40/18	SES	1	56			SICl	CL*	10*	25*	65*	5-10*	10-20*	TNT	27.20	27.20			0.00
101	40/18	SES	1	57			SICl	CL*	10*	25*	65*	5-10*	10-20*	TNT	27.20	27.20			0.00
102	40/18	SES	1	58			SICl	CL*	10*	25*	65*	5-10*	10-20*	TNT	27.20	27.20			0.00
103	40/18	SES	1	59			SICl	CL*	10*	25*	65*	5-10*	10-20*	TNT	27.20	27.20			0.00
104	40/18	SES	1	60			SICl	CL*	10*	25*	65*	5-10*	10-20*	TNT	27.20	27.20			0.00
105	40/28	DP	1	3			SICl	CL*	10*	25*	65*	5-10*	10-20*	TNT	18100.00	18100.00			0.00
106	40/28	DP	1	5			SICl	CL*	10*	25*	65*	5-10*	10-20*	TNT	18100.00	18100.00			0.00

DRY DESERT ALLUVIUM

ROW	REF/SR	TEST P/S	A OBS	SHOT ID	X COORD	Y COORD	SOIL DES	USCS	SA,%	SI,%	CL,%	MC,%	DESA,%	TYPE CH	CH WT,kg	E TNT,kg	TN C/M	MD D/A	H/DOB,R
107	40/31	SC II	1	9-12			DDALLUV	SW,SM*	75*	20*	5*	15*	25*	TNT	116.00	116.00			0.00
108	40/31	SC II	1	9-13			DDALLUV	SW,SM*	75*	20*	5*	15*	25*	TNT	116.00	116.00			0.00

MOIST SANDY SILT

ROW	REF/SR	TEST P/S	A OBS	SHOT ID	X COORD	Y COORD	SOIL DES	USCS	SA,%	SI,%	CL,%	MC,%	DESA,%	TYPE CH	CH WT,kg	E TNT,kg	TN C/M	MD D/A	H/DOB,R
109	40/3	STAMS	1	70-6			MSaSilt	SM*				15*	25*	TNT	1.81	1.81			2.30
110	40/3	STAMS	1	1-L			MSaSilt	SM*				15*	25*	TNT	7.26	7.26			0.50
111	40/3	STAMS	1	16			MSaSilt	SM*				15*	25*	TNT	1.81	1.81			0.50
112	40/3	STAMS	1	70-5			MSaSilt	SM*				15*	25*	TNT	1.81	1.81			0.80
113	40/3	STAMS	1	70-1			MSaSilt	SM*				15*	25*	TNT	1.81	1.81			0.00
114	40/3	STAMS	1	70-2			MSaSilt	SM*				15*	25*	TNT	1.81	1.81			0.00
115	40/3	STAMS	1	70-3			MSaSilt	SM*				15*	25*	TNT	1.81	1.81			0.00
116	40/3	STAMS	1	70-4			MSaSilt	SM*				15*	25*	TNT	1.81	1.81			0.00

(Continued)

Table 1 (Continued)

ROW	SHOT ID	re,m	de,m	Ve,m3	rt,m	dt,m	Vt,m3	Ve'm3/We	Ve/Wn	Vt'm3/kg	Vt/Wn	Ve,m3	We,kg	Ejec Cal	D C Obs	Ke	V/C Obs
91	17	0.37	0.27	5.23E-2*				1.70E-2*	1.25E-2*			3.86E-2*		ve=0.7ve		0.45/-	
92	18	0.31	0.31	4.21E-2*				1.37E-2*	1.01E-2*			2.85E-2*		ve=0.7ve		0.45/-	
93	19	0.43	0.40	1.05E-1*				3.42E-2*	2.51E-2*			7.35E-2*		ve=0.7ve		0.45/-	
94	20	0.31	0.31	4.21E-2*				1.37E-2*	1.01E-2*			2.95E-2*		ve=0.7ve		0.45/-	
95	51	0.67	0.61	3.87E-1*				2.18E-2*	9.88E-3*			2.71E-1*		ve=0.7ve		0.45/-	
96	52	0.70	0.70	4.85E-1*				2.73E-2*	1.24E-2*			3.40E-1*		ve=0.7ve		0.45/-	
97	53	0.73	0.64	4.82E-1*				2.72E-2*	1.23E-2*			3.37E-1*		ve=0.7ve		0.45/-	
98	54	0.70	0.73	5.08E-1*				2.86E-2*	1.29E-2*			3.64E-1*		ve=0.7ve		0.45/-	
99	55	0.73	0.73	5.50E-1*				3.10E-2*	1.40E-2*			3.85E-1*		ve=0.7ve		0.45/-	
100	56	0.85	0.73	7.48E-1*				4.21E-2*	1.90E-2*			5.22E-1*		ve=0.7ve		0.45/-	
101	57	0.88	0.67	7.34E-1*				4.15E-2*	1.87E-2*			5.14E-1*		ve=0.7ve		0.45/-	
102	58	0.84	0.73	9.12E-1*				5.15E-2*	2.33E-2*			6.38E-1*		ve=0.7ve		0.45/-	
103	59	0.73	0.55	4.14E-1*				2.34E-2*	1.06E-2*			2.90E-1*		ve=0.7ve		0.45/-	
104	60	0.73	0.61	4.60E-1*				2.60E-2*	1.17E-2*			3.22E-1*		ve=0.7ve		0.45/-	
105	2	11.00	4.90	836*				1.88E-1*	1.68E-2*							0.45/-	
106	5	10.00	4.30	808*				1.20E-1*	3.38E-2*							0.45/-	

DRY DESERT ALLUVIUM

ROW	SHOT ID	re,m	de,m	Ve,m3	rt,m	dt,m	Vt,m3	Ve'm3/We	Ve/Wn	Vt'm3/kg	Vt/Wn	Ve,m3	We,kg	Ejec Cal	D C Obs	Ke	V/C Obs
107	8-12	2.80	0.78	7.41				1.18E-1	3.77E-2			5.93		ve=0.8ve			
108	8-13	2.50	0.79	7.57				1.21E-1	3.85E-2			6.06		ve=0.8ve			

MOIST SANDY SILT

ROW	SHOT ID	re,m	de,m	Ve,m3	rt,m	dt,m	Vt,m3	Ve'm3/We	Ve/Wn	Vt'm3/kg	Vt/Wn	Ve,m3	We,kg	Ejec Cal	D C Obs	Ke	V/C Obs
109	70-6	0.59	0.08	2.85E-2				1.70E-2*	1.47E-2*			2.00E-2*		ve=0.7ve			
110	1-L	0.82	0.48	4.66E-1*				9.31E-2*	5.15E-2*			3.26E-1*		ve=0.7ve			
111	16	0.62	0.18	6.88E-2*				4.10E-2*	3.58E-2*			4.82E-2*		ve=0.7ve			
112	70-5	0.59	0.15	5.74E-2*				3.42E-2*	2.97E-2*			4.02E-2*		ve=0.7ve			
113	70-1	0.66	0.27	1.15E-1*				6.88E-2*	5.95E-2*			8.05E-2*		ve=0.7ve			
114	70-2	0.62	0.27	1.03E-1*				6.15E-2*	5.33E-2*			7.21E-2*		ve=0.7ve			
115	70-3	0.81	0.30	1.58E-1*				9.43E-2*	8.17E-2*			1.11E-1*		ve=0.7ve			
116	70-4	0.87	0.31	1.97E-1*				1.18E-1*	1.02E-1*			1.38E-1*		ve=0.7ve			

(Continued)

(Sheet 6 of 10)

Table 1 (Continued)

ROW	REF/SR	TEST P/S	A OBS	SHOT ID	X COORD	Y COORD	SOIL DES	USCS	SA.%	SI.%	CL.%	MC.%	DEGA.%	TYPE CH	CH WT.kg	E TNT.kg	TN C/N	ND D/A	H/DOB.R
117	40/13	CSSC	1	1C19			DTMSAND	SW,SM*	90*	5*	5*	0-10*	0-10*	PENT	0.46	0.53			3.50
118	40/13	CSSC	1	5C3			DTMSAND	SW,SM*	90*	5*	5*	0-10*	0-10*	PENT		2.40			3.50
119	40/13	CSSC	1	5C4			DTMSAND	SW,SM*	90*	5*	5*	0-10*	0-10*	PENT		2.40			3.60
120	40/13	CSSC	1	1C10			DTMSAND	SW,SM*	90*	5*	5*	0-10*	0-10*	PENT		0.52			3.50
121	40/13	CSSC	1	1C9			DTMSAND	SW,SM*	90*	5*	5*	0-10*	0-10*	PENT		0.52			3.50
122	40/14	CDS	1	689			DTMSAND	SW,SM*	100*	0*	0*	<6*	10*	TNT	1.81	1.81			2.80
123	40/14	CDS	1	690			DTMSAND	SW,SM*	100*	0*	0*	<6*	10*	TNT	1.81	1.81			2.80
124	40/14	CDS	1	691			DTMSAND	SW,SM*	100*	0*	0*	<6*	10*	TNT	1.81	1.81			2.30
125	40/14	CDS	1	692			DTMSAND	SW,SM*	100*	0*	0*	<6*	10*	TNT	1.81	1.81			2.30
126	40/13	CSSC	1	1C11			DTMSAND	SW,SM*	90*	5*	5*	0-10*	0-10*	PENT		0.53			1.70
127	40/13	CSSC	1	1C12			DTMSAND	SW,SM*	90*	5*	5*	0-10*	0-10*	PENT		0.53			1.70
128	40/14	CDS	1	693			DTMSAND	SW,SM*	100*	0*	0*	<6*	10*	TNT	1.81	1.81			1.40
129	40/14	CDS	1	694			DTMSAND	SW,SM*	100*	0*	0*	<6*	10*	TNT	1.81	1.81			1.40
130	40/14	CDS	1	695			DTMSAND	SW,SM*	100*	0*	0*	<6*	10*	TNT	1.81	1.81			1.00
131	40/14	CDS	1	696			DTMSAND	SW,SM*	100*	0*	0*	<6*	10*	TNT	1.81	1.81			1.00
132	40/13	CSSC	1	1C24			DTMSAND	SW,SM*	90*	5*	5*	0-10*	0-10*	PENT		0.53			0.60
133	40/13	CSSC	1	1C15			DTMSAND	SW,SM*	90*	5*	5*	0-10*	0-10*	PENT		0.53			0.00
134	40/13	CSSC	1	1C14			DTMSAND	SW,SM*	90*	5*	5*	0-10*	0-10*	PENT		0.53			0.00
135	40/13	CSSC	1	1C13			DTMSAND	SW,SM*	90*	5*	5*	0-10*	0-10*	PENT		0.53			0.00
136	40/14	CDS	1	697			DTMSAND	SW,SM*	100*	0*	0*	<6*	10*	TNT	1.81	1.81			0.00
137	40/14	CDS	1	698			DTMSAND	SW,SM*	100*	0*	0*	<6*	10*	TNT	1.81	1.81			0.00
138	40/13	CSSC	1	5C5			DTMSAND	SW,SM*	90*	5*	5*	0-10*	0-10*	PENT		2.40			0.00
139	40/29	ESRIC	1	1			DTMSAND	SW,SM*	90*	5*	5*	0-10*	0-10*	C4	12.20	11.70			0.00
140	40/29	ESRIC	1	2			DTMSAND	SW,SM*	90*	5*	5*	0-10*	0-10*	C4	12.20	11.70			0.00
141	40/29	ESRIC	1	10			DTMSAND	SW,SM*	90*	5*	5*	0-10*	0-10*	C4	12.20	11.70			0.00
142	40/29	ESRIC	1	11			DTMSAND	SW,SM*	90*	5*	5*	0-10*	0-10*	C4	12.20	11.70			0.00
143	40/29	ESRIC	1	3			DTMSAND	SW,SM*	90*	5*	5*	0-10*	0-10*	C4		15.90			0.00
144	40/29	ESRIC	1	4			DTMSAND	SW,SM*	90*	5*	5*	0-10*	0-10*	C4		15.90			0.00
145	40/29	ESRIC	1	12			DTMSAND	SW,SM*	90*	5*	5*	0-10*	0-10*	C4		15.90			0.00
146	40/29	ESRIC	1	13			DTMSAND	SW,SM*	90*	5*	5*	0-10*	0-10*	C4		15.90			0.00
147	40/29	ESRIC	1	5			DTMSAND	SW,SM*	90*	5*	5*	0-10*	0-10*	TNT	116.00	116.00			0.00
148	40/29	ESRIC	1	6			DTMSAND	SW,SM*	90*	5*	5*	0-10*	0-10*	TNT	116.00	116.00			0.00
149	40/29	ESRIC	1	8			DTMSAND	SW,SM*	90*	5*	5*	0-10*	0-10*	TNT	116.00	116.00			0.00
150	40/29	ESRIC	1	9			DTMSAND	SW,SM*	90*	5*	5*	0-10*	0-10*	TNT	116.00	116.00			0.00
151	40/63	ZUL	1	01			DTMSAND	SW,SM*	90*	5*	5*	0-10*	0-10*	C4		0.45			0.00
152	40/63	ZUL	1	02			DTMSAND	SW,SM*	90*	5*	5*	0-10*	0-10*	C4		0.45			0.00
153	40/14	CDS	1	699			DTMSAND	SW,SM*	100*	0*	0*	<6*	10*	TNT	1.81	1.81			-1.00
154	40/14	CDS	1	700			DTMSAND	SW,SM*	100*	0*	0*	<6*	10*	TNT	1.81	1.81			-1.00
155	40/38	J HE	1	9			DTMSAND	SW,SM*	90*	5*	5*	0-10*	0-10*	TNT	98.00	98.00			-1.00
156	40/38	J HE	1	9A			DTMSAND	SW,SM*	90*	5*	5*	0-10*	0-10*	TNT	83.40	83.40			-1.00
157	40/38	J HE	1	8			DTMSAND	SW,SM*	90*	5*	5*	0-10*	0-10*	TNT	83.40	83.40			-1.40
158	40/13	CSSC	1	1C17			DTMSAND	SW,SM*	90*	5*	5*	0-10*	0-10*	PENT		0.53			-2.00
159	40/13	CSSC	1	1C16			DTMSAND	SW,SM*	90*	5*	5*	0-10*	0-10*	PENT		0.53			-2.00
160	40/14	CDS	1	701			DTMSAND	SW,SM*	100*	0*	0*	<6*	10*	TNT	1.81	1.81			-2.00
161	40/14	CDS	1	702			DTMSAND	SW,SM*	100*	0*	0*	<6*	10*	TNT	1.81	1.81			-2.00
162	40/13	CSSC	1	1C20			DTMSAND	SW,SM*	90*	5*	5*	0-10*	0-10*	PENT		0.53			-3.70
163	40/13	CSSC	1	1C18			DTMSAND	SW,SM*	90*	5*	5*	0-10*	0-10*	PENT		0.53			-3.70
164	40/63	ZUL	1	03			DTMSAND	SW,SM*	90*	5*	5*	0-10*	0-10*	C4		0.45			-3.70
165	40/63	ZUL	1	04			DTMSAND	SW,SM*	90*	5*	5*	0-10*	0-10*	C4		0.45			-3.70
166	40/63	ZUL	1	05			DTMSAND	SW,SM*	90*	5*	5*	0-10*	0-10*	C4		0.45			-3.70

(Continued)

Table 1 (Continued)

ROW	SHOT ID	re,m	de,m	Ve,m3	rt,m	dt,m	Vt,m3	Ve'm3/We	Ve/Wn	Vt'm3/kg	Vt/Wn	Vo,m3	We,kg	Ejec Cat	D C Obs	Ke	V/C Obs
117	1C19	0.34	0.03	4.90E-3*				9.43E-3*	9.82E-3*			3.82E-3*		ve-0.8ve			
118	5C3	0.55	0.06	5.70E-2				2.67E-2	2.18E-2			4.56E-2		ve-0.8ve			
119	5C4	0.59	0.09	2.80E-2				1.31E-2*	1.06E-2*			2.24E-2		ve-0.8ve			
120	1C10	0.34	0.03	4.90E-3*				8.82E-3*	1.01E-2*			3.92E-3*		ve-0.8ve		0.45/-	
121	1C9	0.40	0.03	6.79E-3*				1.19E-2*	1.40E-2*			5.43E-3*		ve-0.8ve		0.45/-	
122	689	0.56	0.06	2.57E-2*				1.53E-2*	1.33E-2*			2.06E-2*		ve-0.8ve		0.45/-	
123	690	0.56	0.06	2.57E-2*				1.53E-2*	1.33E-2*			2.06E-2*		ve-0.8ve		0.45/-	
124	691	0.62	0.09	3.44E-2*				2.06E-2*	1.78E-2*			2.75E-2*		ve-0.8ve		0.45/-	
125	692	0.52	0.06	2.29E-2*				1.37E-2*	1.18E-2*			1.83E-2*		ve-0.8ve		0.45/-	
126	1C11	0.37	0.09	1.16E-2*				2.00E-2*	2.32E-2*			9.28E-3*		ve-0.8ve		0.45/-	
127	1C12	0.31	0.06	8.15E-3*				1.40E-2*	1.63E-2*			6.52E-3*		ve-0.8ve		0.45/-	
128	693	0.62	0.09	3.44E-2*				2.06E-2*	1.78E-2*			2.75E-2*		ve-0.8ve		0.45/-	
129	694	0.68	0.09	4.28E-2*				2.56E-2*	2.21E-2*			3.42E-2*		ve-0.8ve		0.45/-	
130	695	0.87	0.15	9.52E-2*				5.69E-2*	4.92E-2*			4.76E-2*		ve-0.5ve		0.45/-	
131	696	0.94	0.19	1.04E-1*				6.21E-2*	5.38E-2*			5.20E-2*		ve-0.5ve		0.45/-	
132	1C24	0.62	0.18	5.72E-2				9.85E-2	1.16E-1			2.86E-2		ve-0.5ve			
133	1C15	0.65	0.24	8.51E-2				1.46E-1	1.71E-1			4.26E-2		ve-0.5ve			
134	1C14	0.62	0.21	8.51E-2				1.46E-1	1.71E-1			4.26E-2		ve-0.5ve			
135	1C13	0.49	0.15	5.70E-2				9.85E-2	1.14E-1			2.85E-2		ve-0.5ve			
136	697	0.79	0.27	2.36E-1*				1.42E-1*	1.23E-1*			1.18E-1*		ve-0.5ve		0.45/-	
137	698	0.76	0.24	1.96E-1*				1.17E-1*	1.01E-1*			9.80E-2*		ve-0.5ve		0.45/-	
138	5C5	0.92	0.27	2.83E-1				1.32E-1	1.07E-1			1.42E-1		ve-0.5ve			
139	1	1.29	0.58	1.53				1.80E-1	9.95E-2			7.65E-1		ve-0.5ve			
140	2	1.37	0.67	1.99				2.31E-1	1.27E-1			9.90E-1		ve-0.5ve			
141	10	1.37	0.70	1.73				2.04E-1	1.13E-1			8.65E-1		ve-0.5ve			
142	11	1.29	0.67	1.36				1.60E-1	8.85E-2			6.80E-1		ve-0.5ve			
143	3	1.62	0.87	2.32				2.09E-1	1.07E-1			1.16		ve-0.5ve			
144	4	1.62	0.84	2.08				1.88E-1	9.67E-2			1.04		ve-0.5ve			
145	12	1.40	0.70	1.96				1.76E-1	9.07E-2			9.80E-1		ve-0.5ve			
146	13	1.49	0.73	2.07				1.86E-1	9.59E-2			1.04		ve-0.5ve			
147	5	2.59	1.04	11.9				1.91E-1	6.06E-2			5.95		ve-0.5ve			
148	6	2.62	1.07	11.1				1.78E-1	5.66E-2			5.55		ve-0.5ve			
149	7	2.66	1.28	11.2				1.79E-1	5.70E-2			5.60		ve-0.5ve			
150	8	2.90	1.34	15.3				2.45E-1	7.78E-2			7.65		ve-0.5ve			
151	01	0.40	0.15	3.39E-2*				6.73E-2*	8.15E-2*			1.70E-2*		ve-0.5ve		0.45/-	
152	02	0.43	0.15	3.92E-2*				7.78E-2*	9.43E-2*			1.96E-2*		ve-0.5ve		0.45/-	
153	699	0.92	0.37	4.43E-1*				2.65E-1*	2.29E-1*			3.10E-1*		ve-0.7ve		0.45/-	
154	700	0.94	0.37	4.62E-1*				2.76E-1*	2.39E-1*			3.23E-1*		ve-0.7ve		0.45/-	
155	9	2.53	1.07	7.65				1.42E-1	4.89E-2			5.36		ve-0.7ve			
156	9A	2.62	1.04	8.22				1.75E-1	6.03E-2			5.75		ve-0.7ve			
157	9	2.66	1.01	10.8				2.29E-1	7.93E-2			7.56		ve-0.7ve			
158	1C17	0.67	0.30	2.27E-1				3.90E-1	4.55E-1			1.59E-1		ve-0.7ve			
159	1C18	0.70	0.34	2.56E-1				4.39E-1	5.11E-1			1.79E-1		ve-0.7ve			
160	701	1.04	0.43	6.58E-1*				3.93E-1*	3.40E-1*			4.61E-1*		ve-0.7ve		0.45/-	
161	702	1.04	0.43	6.58E-1*				3.93E-1*	3.40E-1*			4.61E-1*		ve-0.7ve		0.45/	
162	1C20	0.70	0.37	2.27E-1				3.90E-1	4.55E-1			1.59E-1		ve-0.7ve			
163	1C19	0.79	0.40	3.40E-1				5.89E-1	6.81E-1			2.38E-1		ve-0.7ve			
164	03	0.64	0.30	1.74E-1*				3.46E-1*	4.19E-1*			1.22E-1*		ve-0.7ve		0.45/-	
165	04	0.70	0.30	2.08E-1*				4.13E-1*	5.00E-1*			1.46E-1*		ve-0.7ve		0.45/-	
166	05	0.70	0.34	2.36E-1*				4.69E-1*	5.67E-1			1.65E-1*		ve-0.7ve		0.45/-	

(Continued)

Table 1 (Continued)

ROW	REF/SR	TEST P/S	A OBS	SHOT ID	X COORD	Y COORD	SOIL DES	USCS	SA,%	SI,%	CL,%	MC,%	DESA,%	TYPE CH	CH WT,kg	E TNT,kg	TN C/N	NO D/A	H/DOB,R
167	40/60	UETP	1	101			WET SAND	SW*	90*	5*	5*			TNT	145.00	145.00			3.75
168	40/13	CSSC	1	1A26			WET SAND	SW*	90*	5*	5*			PENT		0.53			3.00
169	40/13	CSSC	1	1A27			WET SAND	SW*	90*	5*	5*			PENT		0.53			3.00
170	40/13	CSSC	1	1A25			WET SAND	SW*	90*	5*	5*			PENT		0.53			3.00
171	40/45	MOLE	1	207			WET SAND	SW*	90*	5*	5*			TNT	116.00	116.00			1.00
172	40/45	MOLE	1	308			WET SAND	SW*	90*	5*	5*			TNT	116.00	116.00			1.00
173	40/13	CSSC	1	5A41			WET SAND	SW*	90*	5*	5*			PENT		2.49			1.00
174	40/13	CSSC	1	1A16			WET SAND	SW*	90*	5*	5*			PENT		0.53			0.00
175	40/29	ESRIC	1	31			WET SAND	SW*	90*	5*	5*			C4	12.20	11.70			0.00
176	40/29	ESRIC	1	32			WET SAND	SW*	90*	5*	5*			C4	12.20	11.70			0.00
177	40/45	MOLE	1	206			WET SAND	SW*	90*	5*	5*			TNT	116.00	116.00			0.00
178	40/45	MOLE	1	307			WET SAND	SW*	90*	5*	5*			TNT	116.00	116.00			0.00
179	40/13	CSSC	1	1A17			WET SAND	SW*	90*	5*	5*			PENT		0.53			-1.00
180	40/13	CSSC	1	1A18			WET SAND	SW*	90*	5*	5*			PENT		0.53			-1.00
181	40/13	CSSC	1	1A19			WET SAND	SW*	90*	5*	5*			PENT		0.53			-1.00
182	40/13	CSSC	1	5A42			WET SAND	SW*	90*	5*	5*			PENT		2.64			-3.00
183	40/45	MOLE	1	205			WET SAND	SW*	90*	5*	5*			TNT	116.00	118.00			-1.00
184	40/45	MOLE	1	306			WET SAND	SW*	90*	5*	5*			TNT	116.00	116.00			-1.00
185	40/45	MOLE	1	403			WET SAND	SW*	90*	5*	5*			TNT	116.00	116.00			-1.00

BASALT AND GRANITE

ROW	REF/SR	TEST P/S	A OBS	SHOT ID	X COORD	Y COORD	SOIL DES	USCS	SA,%	SI,%	CL,%	MC,%	DESA,%	TYPE CH	CH WT,kg	E TNT,kg	TN C/N	NO D/A	H/DOB,R
186	40/20	ICSBA	1	14			ROCK B-G							TNT	11.30	11.30			0.00
187	40/20	ICSBA	1	151A			ROCK B-G							TNT	91.00	91.00			0.00
188	40/20	ICSBA	1	162A			ROCK B-G							TNT	91.00	91.00			0.00
189	40/20	ICSBA	1	173A			ROCK B-G							TNT	91.00	91.00			-1.50
190	40/20	ICSBA	1	184A			ROCK B-G							TNT	91.00	91.00			-1.50

SANDSTONE

ROW	REF/SR	TEST P/S	A OBS	SHOT ID	X COORD	Y COORD	SOIL DES	USCS	SA,%	SI,%	CL,%	MC,%	DESA,%	TYPE CH	CH WT,kg	E TNT,kg	TN C/N	NO D/A	H/DOB,R
191	40/22	ICSSS	1	16			SANDST							TNT	11.30	11.30			0.00

SHALE, TUFF, OR FROZEN GROUND

ROW	REF/SR	TEST P/S	A OBS	SHOT ID	X COORD	Y COORD	SOIL DES	USCS	SA,%	SI,%	CL,%	MC,%	DESA,%	TYPE CH	CH WT,kg	E TNT,kg	TN C/N	NO D/A	H/DOB,R
192	40/21	ICSCC	1	04			SH-T-FG							TNT	25.00	25.00			0.00
193	40/21	ICSCC	1	13			SH-T-FG							TNT	25.00	25.00			0.00
194	40/21	ICSCC	1	14			SH-T-FG							TNT	50.00	50.00			0.00
195	40/21	ICSCC	1	15			SH-T-FG							TNT	50.00	50.00			0.00
196	40/21	ICSCC	1	16			SH-T-FG							TNT	50.00	50.00			-1.20

(Continued)

Table 1 (Concluded)

WET SAND

ROW	SHOT ID	re,m	de,m	Ve,m3	rt,m	dt,m	Vt,m3	Va'm3/We	Va/Wn	Vt'm3/kg	Vt/Wn	Ve,m3	We,kg	Ejec Cal	D C Obs	Ks	V/C Obs
167	101	1.22	0.15	3.20E-1*				4.22E-3*	1.27E-3*			2.24E-1*		ve=0.7va		0.45/-	
168	1A28	0.43	0.09	7.84E-3*				1.36E-1*	1.57E-1*			5.48E-3*		ve=0.7va		0.45/-	
169	1A27	0.40	0.03	6.78E-3*				1.17E-1*	1.38E-1*			4.75E-3*		ve=0.7va		0.45/-	
170	1A26	0.37	0.12	2.32E-2*				4.00E-2*	4.65E-2*			1.62E-2*		ve=0.7va		0.45/-	
171	207	1.22	0.43	1.05			12.6	1.88E-2	5.34E-3	1.10E-1	6.61E-2	1.47		ve=0.67va+0.06vt			
172	308	2.71	1.22	12.7				2.02E-1	6.48E-2			17.8		ve=1.4va			
173	5A41	0.55	0.21	8.98E-2*				4.08E-2*	3.28E-2*			1.37E-1*		ve=1.4va		0.45/-	
174	1A18	0.84	0.15	8.88E-2*				1.48E-1*	1.74E-1*			7.82E-2*		ve=0.8va		0.45/-	
175	31	1.34	0.73	1.53				1.80E-1	9.95E-2			1.38		ve=0.8va			
176	32	1.22	0.67	1.33				1.57E-1	8.85E-2			1.20		ve=0.8va			
177	206	1.82	0.52	3.88			16.3	5.88E-1	1.88E-2	1.41E-1	8.29E-2	3.43		ve=0.67va+0.06vt			
178	307	3.83	1.43	37.3				5.97E-1	1.90E-1			33.6		ve=0.8va			
179	1A17	0.58	0.21	9.98E-2*				1.72E-1*	2.00E-1*			7.98E-2*		ve=0.8va		0.45/-	
180	1A19	0.58	0.21	9.98E-2*				1.72E-1*	2.00E-1*			7.98E-2*		ve=0.8va		0.45/-	
181	1A18	0.61	0.24	1.28E-1*				2.17E-1*	2.52E-1*			1.00E-1*		ve=0.8va		0.45/-	
182	5A42	0.84	0.42	5.28E-1*				2.34E-1*	1.88E-1*			4.2E-1*		ve=0.8va		0.45/-	
183	205	2.74	0.61	8.50			20.4	1.38E-1	4.32E-2	1.76E-1	1.04E-1	6.92		ve=0.67va+0.06vt			
184	308	3.88	1.18	38.0				6.23E-1	1.98E-1			31.2		ve=0.8va			
185	403	2.53	1.04	6.30				1.33E-1	4.22E-2			8.64		ve=0.8va			

BASALT AND GRANITE

ROW	SHOT ID	re,m	de,m	Ve,m3	rt,m	dt,m	Vt,m3	Va'm3/We	Va/Wn	Vt'm3/kg	Vt/Wn	Ve,m3	We,kg	Ejec Cal	D C Obs	Ks	V/C Obs
186	14	0.61	0.21	1.70E-1	0.84	0.48	6.23E-1	2.08E-2	1.15E-2	5.51E-2	4.21E-2						
187	151A	1.40	0.49	1.39	2.18	1.01	7.79	2.75E-2	9.26E-3	9.58E-2	5.19E-2						
188	192A	1.82	0.37	1.79	2.18	0.79	5.70	3.54E-2	1.19E-2	9.28E-2	3.80E-2						
189	173A	1.68	0.40	1.22	2.41	0.87	10.3	2.41E-2	8.13E-3	1.13E-1	8.88E-2						
190	184A	1.13	0.33	8.50E-1	2.29	1.22	10.7	1.68E-2	5.88E-3	1.18E-1	7.13E-2						

SANDSTONE

ROW	SHOT ID	re,m	de,m	Ve,m3	rt,m	dt,m	Vt,m3	Va'm3/We	Va/Wn	Vt'm3/kg	Vt/Wn	Ve,m3	We,kg	Ejec Cal	D C Obs	Ks	V/C Obs
191	18	1.04	0.24	3.73E-1*	1.18	0.33	8.78E-1	4.52E-2	2.52E-2	7.77E-2	5.84E-2					0.45/-	

SHALE, TUFF, OR FROZEN GROUND

ROW	SHOT ID	re,m	de,m	Ve,m3	rt,m	dt,m	Vt,m3	Va'm3/We	Va/Wn	Vt'm3/kg	Vt/Wn	Ve,m3	We,kg	Ejec Cal	D C Obs	Ks	V/C Obs
192	D4	1.31	0.48	1.08	1.74	0.64	2.55	6.58E-2	3.02E-2	1.02E-1	7.14E-2						
193	13	1.13	0.55	1.11	1.86	0.78	3.12	6.75E-2	3.11E-2	1.25E-1	8.73E-2						
194	14	2.29	0.94	6.89	2.68	1.07	10.6	2.23E-1	8.67E-2	2.12E-1	1.37E-1						
195	15	2.88	1.18	11.8*	2.77	1.28	12.4*	3.82E-1*	1.53E-1*	2.48E-1*	1.81E-1*					0.45/0.40	
196	16	2.18	0.78	4.89	2.32	0.81	7.65	1.88E-1	6.48E-2	1.53E-1	9.91E-2						

Table 2

Cratering Data from WES Experiments in Wet Sand and from Munitions/Bare-Charge Equivalence II Study

BBTS EXPERIMENTS WET UNIFORM MASONRY SAND

ROW	REF/SR	TEST P/S	A OBS	SHOT ID	X COORD	Y COORD	SOIL DES	USCS	SA,%	SI,%	CL,%	MC,%	DESA,%	TYPE CH	CH WT,kg	E TNT,kg	TN C/M	NO D/A	H/DOB,R
197	8	BBTS	1	1-1			WetSand	SP	100*	0*	0*	15*	25*	TNT	0.45	0.45			1.00
198	8	BBTS	1	1-2			WetSand	SP	100*	0*	0*	15*	25*	TNT	0.45	0.45			0.00
199	8	BBTS	1	1-5			WetSand	SP	100*	0*	0*	15*	25*	TNT	1.81	1.81			1.00
200	8	BBTS	1	1-6			WetSand	SP	100*	0*	0*	15*	25*	TNT	1.81	1.81			0.00
201	8	BBTS	1	1-9			WetSand	SP	100*	0*	0*	15*	25*	TNT	7.26	7.26			1.00
202	8	BBTS	1	1-10			WetSand	SP	100*	0*	0*	15*	25*	TNT	7.26	7.26			0.00
203	8	BBTS	1	1-25			WetSand	SP	100*	0*	0*	15*	25*	TNT	2.40	2.40			1.00
204	8	BBTS	1	1-26			WetSand	SP	100*	0*	0*	15*	25*	TNT	2.40	2.40			0.00
205	8	BBTS	1	1-33			WetSand	SP	100*	0*	0*	15*	25*	TNT	7.26	7.26			1.00
206	8	BBTS	1	1-34			WetSand	SP	100*	0*	0*	15*	25*	TNT	7.26	7.26			0.00

FORT POLK,LA. (RANGE 37) SANDY CLAY

ROW	REF/SR	TEST P/S	A OBS	SHOT ID	X COORD	Y COORD	SOIL DES	USCS	SA,%	SI,%	CL,%	MC,%	DESA,%	TYPE CH	CH WT,kg	E TNT,kg	TN C/M	NO D/A	H/DOB,R
207	29	MBCE-II	1	C1			SaCl	CL	30*	10*	60*	AVG 20	40*	C4	12.00	11.40			1.00
208	29	MBCE-II	1	C2			SaCl	CL	30*	10*	60*	AVG 20	40*	C4	12.00	11.40			1.00
209	29	MBCE-II	1	C3			SaCl	CL	30*	10*	60*	AVG 20	40*	C4	12.00	11.40			1.00
210	29	MBCE-II	1	C4			SaCl	CL	30*	10*	60*	AVG 20	40*	C4	6.80	6.50			1.00
211	29	MBCE-II	1	C5			SaCl	CL	30*	10*	60*	AVG 20	40*	C4	6.80	6.50			-1.00

BBTS EXPERIMENTS WET UNIFORM MASONRY SAND

ROW	SHOT ID	re,m	de,m	Ve,m3	rt,m	dt,m	Vt,m3	Ve'm3/We	Va/Wn	Vt'm3/kg	Vt/Wn	Va,m3	We,kg	Ejec Cal	O C Obs	Ke	V/C Des
197	1-1	0.38	0.12	2.45E-2*				4.67E-2*	5.88E-2*			3.43E-2*		ve=1.4va		0.45/-	
198	1-2	0.48	0.14	4.56E-2*				9.01E-2*	1.10E-1*			4.10E-2*		ve=0.9va		0.45/-	
199	1-5	0.54	0.18	6.60E-2*				3.94E-2*	3.41E-2*			9.24E-2*		ve=1.4va		0.45/-	
200	1-6	0.73	0.25	1.88E-1*				1.12E-1*	9.72E-2*			1.69E-1*		ve=0.9va		0.45/-	
201	1-9	0.81	0.23	2.13E-1*				3.79E-2*	2.35E-2*			2.98E-1*		ve=1.4va		0.45/-	
202	1-10	1.14	0.42	7.72E-1*				1.37E-1*	8.53E-2*			6.95E-1*		ve=0.9va		0.45/-	
203	1-25	0.59	0.14	6.89E-2*				3.12E-2*	2.50E-2*			9.83E-2*		ve=1.4va		0.45/-	
204	1-26	0.75	0.28	2.07E-1*				9.38E-2*	7.51E-2*			1.88E-1*		ve=0.9va		0.45/-	
205	1-33	0.78	0.20	1.78E-1*				3.13E-2*	1.95E-2*			2.48E-1*		ve=1.4va		0.45/-	
206	1-34	1.01	0.32	4.82E-1*				8.23E-2*	5.11E-2*			4.18E-1*		ve=0.9va		0.45/-	

FORT POLK,LA. (RANGE 37) SANDY CLAY

ROW	SHOT ID	re,m	de,m	Ve,m3	rt,m	dt,m	Vt,m3	Ve'm3/We	Va/Wn	Vt'm3/kg	Vt/Wn	Va,m3	We,kg	Ejec Cal	O C Obs	Ke	V/C Des
207	C1	1.09	0.69	1.14*				1.37E-1*	7.63E-2*			7.08E-1*		ve=0.7va			
208	C2	1.24	0.71	1.54*				1.85E-1*	1.03E-1*			1.08*		ve=0.7va			
209	C3	0.94	0.68	0.85*				1.02E-1*	5.89E-2*			6.00E-1*		ve=0.7va			
210	C4	1.43	0.87	2.52*				4.86E-1*	3.16E-1*			1.78*		ve=0.7va			
211	C5	1.49	0.89	3.03*				5.94E-1*	3.78E-1*			2.12*		ve=0.7va			

Table 3

Cratering Data from the Mono Lake Experiments

MONO LAKE,CA. (SOUTH SHORE) PUMICE SAND

ROW	REF/SR	TEST P/S	A OBS	SHOT ID	X COORD	Y COORD	SOIL DES	USCS	SA,%	SI,%	CL,%	MC,%	DESA,%	TYPE CH	CH WT,kg	E TNT,kg	TM C/M	MD D/A	H/DOB,R
212	9	MONOLAKE	1	A(2.4)*			PUMSAND	SP*	90*	5*	5*	15*	25*	SL-ANOIL	115.00	115.00			0.00
213	9	MONOLAKE	1	B(1.2)			PUMSAND	SP*	90*	5*	5*	25*	40*	ANOIL	114.00	114.00			0.00
214	9	MONOLAKE	1	C(0.5)			PUMSAND	SP*	90*	5*	5*	30*	50*	ANOIL	114.00	114.00			0.00
215	9	MONOLAKE	1	D(0)			PUMSAND	SP*	90*	5*	5*	45*	100*	SLURRY	115.00	115.00			0.00
216	9	MONOLAKE	1	E(1.2)			PUMSAND	SP*	90*	5*	5*	25*	40*	ANOIL	114.00	114.00			-2.30

MONO LAKE,CA. (SOUTH SHORE) PUMICE SAND

ROW	SHOT ID	ra,m	da,m	Va,m3	rt,m	dt,m	Vt,m3	Va'm3/Wa	Va/Wn	Vt'm3/kg	Vt/Wn	Ve,m3	We,kg	Ejec Cal	D C Obs	Ke	V/C Des
212	A(2.4)	2.26	1.18	6.37				1.03E-1	3.27E-2			3.18		ve=0.5va			
213	B(1.2)	2.23	1.37	8.22				1.33E-1	4.28E-2			2.47		ve=0.3va			
214	C(0.5)	2.96	1.37	18.3				3.13E-1	1.00E-1			1.74E+1		ve=0.9va			
215	D(0)	4.36	1.07	35.4				5.71E-1	1.82E-1			3.18E+1		ve=0.9va			
216	E(1.2)	4.66	1.25	53.8				8.74E-1	2.78E-1			4.30E+1		ve=0.8va			

* The parentheses following the Shot ID entry is the depth to water table.

Table 4

Cratering Data from Smoke Weeks II and III

EGLIN AFB,FL. (TRC5A) UNIFORM SAND

ROW	REF/SR	TEST P/S	A OBS	SHOT ID	X COORD	Y COORD	SOIL DES	USCS	SA.%	SI.%	CL.%	MC.%	DESA.%	TYPE CH	CH WT.kg	E TNT.kg	TN C/N	MD D/A	H/DOB.R
217	28	SMOKE III	1	25N			UNISAND	SP*	80*	10*	10*	<8	20*	C4	2.27	2.16			1.00
218	28	SMOKE III	1	44N			UNISAND	SP*	80*	10*	10*	<8	20*	C4	2.27	2.16			1.00
219	28	SMOKE III	1	12N			UNISAND	SP*	80*	10*	10*	<8	20*	C4	2.27	2.16			1.00
220	28	SMOKE III	1	26N			UNISAND	SP*	80*	10*	10*	<8	20*	C4	2.27	2.16			1.00
221	28	SMOKE III	1	40N			UNISAND	SP*	80*	10*	10*	<8	20*	C4	2.27	2.16			1.00
222	28	SMOKE III	1	41S			UNISAND	SP*	80*	10*	10*	<8	20*	C4	6.80	6.46			1.00
223	28	SMOKE III	1	39S			UNISAND	SP*	80*	10*	10*	<8	20*	C4	6.80	6.46			1.00
224	28	SMOKE III	1	38S			UNISAND	SP*	80*	10*	10*	<8	20*	C4	6.80	6.46			1.00

EGLIN AFB,FL. (TRC5A) UNIFORM SAND

ROW	REF/SR	TEST P/S	A OBS	SHOT ID	X COORD	Y COORD	SOIL DES	USCS	SA.%	SI.%	CL.%	MC.%	DESA.%	TYPE CH	CH WT.kg	E TNT.kg	TN C/N	MD D/A	H/DOB.R
225	28	SMOKE II	12	AVG			UNISAND	SP*	80*	10*	10*	<8	20*	C4	2.27	2.16			1.00
226	28	SMOKE II	12	AVG			UNISAND	SP*	80*	10*	10*	<8	20*	C4	6.80	6.46			1.00

EGLIN AFB,FL. (TRC5A) UNIFORM SAND

ROW	SHOT ID	ra.m	da.m	Va.m3	rt.m	dt.m	Vt.m3	Va'm3/We	Va/Wn	Vt'm3/kg	Vt/Wn	Ve.m3	We.kg	Ejec Cal	D C Obs	Ke	V/C Des
217	25N	0.75	0.44	3.50E-1*				1.79E-1*	1.49E-1*			7.40E-1*		ve=2.1va		0.45/-	GH&F(50)
218	44N	0.69	0.36	2.42E-1*				1.24E-1*	1.03E-1*			5.10E-1*		ve=2.1va		0.45/-	GH&F(50)
219	12N	0.72	0.38	2.79E-1*				1.43E-1*	1.19E-1*			5.90E-1*		ve=2.1va		0.45/-	GH&F(50)
220	26N	0.78	0.44	3.79E-1*				1.93E-1*	1.61E-1*			8.00E-1*		ve=2.1va		0.45/-	GH&F(50)
221	40N	0.68	0.39	2.40E-1*				1.23E-1*	1.02E-1*			5.00E-1*		ve=2.1va		0.45/-	GH&F(50)
222	41S	1.22	0.35	7.37E-1*				1.46E-1*	9.27E-2*			1.54*	2351.00	D=587.53R-3.191		0.45/-	GH&F(50)
223	39S	1.24	0.50	1.09*				2.15E-1*	1.37E-1*			2.29*		ve=2.1va		0.45/-	GH&F(50)
224	38S	1.09	0.55	9.24E-1*				1.82E-1*	1.16E-1*			1.88*	2877.00	D=543.80R-3.084		0.45/-	GH&F(50)

EGLIN AFB,FL. (TRC5A) UNIFORM SAND

ROW	SHOT ID	ra.m	da.m	Va.m3	rt.m	dt.m	Vt.m3	Va'm3/We	Va/Wn	Vt'm3/kg	Vt/Wn	Ve.m3	We.kg	Ejec Cal	D C Obs	Ke	V/C Des
225	AVG	0.73	0.53	3.98E-1*				2.04E-1*	1.70E-1*			8.40E-1*		ve=2.1va		0.45/-	
226	AVG	1.09	0.68	1.11*				2.18E-1*	1.40E-1*			2.33*		ve=2.1va		0.45/-	

Table 5

Cratering Data from Statically Fired Munitions and Bare Charges

Simulating Statically Fired Munitions

WHITE SANDS MISSILE RANGE,NM. (QUEEN 15 AREA) MOIST SILTY CLAY

ROW	REF/GR	TEST P/S	A ORG	SHOT ID	X COORD	Y COORD	SOIL DES	USCS	SA.%	SI.%	CL.%	MC.%	DESA.%	TYPE CH	CH WT.kg	E TNT.kg	TM C/M	MD O/A	W/DOB.R
227	18	MBCE-I	1	C-1			MSICL	CL-ML	15°	35°	50°	10-15°	30°	TNT	3.54	3.54	4.2/M329	ST 60	2.48
228	18	MBCE-I	1	C-4			MSICL	CL-ML	15°	35°	50°	10-15°	30°	TNT	3.54	3.54	4.2/M329	ST 60	2.48
229	18	MBCE-I	1	C-6			MSICL	CL-ML	15°	35°	50°	10-15°	30°	TNT	3.54	3.54	4.2/M329	ST 60	2.48
230	18	MBCE-I	1	C-10			MSICL	CL-ML	15°	35°	50°	10-15°	30°	TNT	3.54	3.54	4.2/M329	ST 60	2.18
231	18	MBCE-I	1	C-7			MSICL	CL-ML	15°	35°	50°	10-15°	30°	TNT	3.54	3.54	4.2/M329	ST 60	2.18
232	18	MBCE-I	1	A-13			MSICL	CL-ML	15°	35°	50°	10-15°	30°	TNT	7.08	7.08	155/M107	ST 30	1.52
233	18	MBCE-I	1	A-14			MSICL	CL-ML	15°	35°	50°	10-15°	30°	TNT	7.08	7.08	155/M107	ST 30	1.52
234	18	MBCE-I	1	A-15			MSICL	CL-ML	15°	35°	50°	10-15°	30°	TNT	7.08	7.08	155/M107	ST 30	1.52
235	18	MBCE-I	1	A-1			MSICL	CL-ML	15°	35°	50°	10-15°	30°	TNT	7.08	7.08	155/M107	ST 20	1.04
236	18	MBCE-I	1	A-4			MSICL	CL-ML	15°	35°	50°	10-15°	30°	TNT	7.08	7.08	155/M107	ST 20	1.04
237	18	MBCE-I	1	E-9			MSICL	CL-ML	15°	35°	50°	10-15°	30°	C4	4.40	4.20			1.00
238	18	MBCE-I	1	E-1			MSICL	CL-ML	15°	35°	50°	10-15°	30°	C4	12.00	11.40			1.00
239	18	MBCE-I	1	E-11			MSICL	CL-ML	15°	35°	50°	10-15°	30°	C4	1.80	1.71			1.00
240	18	MBCE-I	1	E-3			MSICL	CL-ML	15°	35°	50°	10-15°	30°	C4	12.00	11.40			1.00
241	18	MBCE-I	1	E-4			MSICL	CL-ML	15°	35°	50°	10-15°	30°	C4	4.40	4.20			1.00
242	18	MBCE-I	1	B-1			MSICL	CL-ML	15°	35°	50°	10-15°	30°	COMPB	2.20	2.42	105/M1	ST 20	0.88
243	18	MBCE-I	1	B-4			MSICL	CL-ML	15°	35°	50°	10-15°	30°	COMPB	2.20	2.42	105/M1	ST 20	0.88
244	18	MBCE-I	1	B-6			MSICL	CL-ML	15°	35°	50°	10-15°	30°	COMPB	2.20	2.42	105/M1	ST 20	0.88
245	18	MBCE-I	1	A-7			MSICL	CL-ML	15°	35°	50°	10-15°	30°	TNT	7.08	7.08	155/M107	ST 15	0.78
246	18	MBCE-I	1	A-12			MSICL	CL-ML	15°	35°	50°	10-15°	30°	TNT	7.08	7.08	155/M107	ST 11.5	0.61
247	18	MBCE-I	1	A-11			MSICL	CL-ML	15°	35°	50°	10-15°	30°	TNT	7.08	7.08	155/M107	ST 11.5	0.61
248	18	MBCE-I	1	A-10			MSICL	CL-ML	15°	35°	50°	10-15°	30°	TNT	7.08	7.08	155/M107	ST 11.5	0.61
249	18	MBCE-I	1	B-10			MSICL	CL-ML	15°	35°	50°	10-15°	30°	COMPB	2.20	2.42	105/M1	ST 10	0.42
250	18	MBCE-I	1	B-12			MSICL	CL-ML	15°	35°	50°	10-15°	30°	COMPB	2.20	2.42	105/M1	ST 10	0.42
251	18	MBCE-I	1	B-7			MSICL	CL-ML	15°	35°	50°	10-15°	30°	COMPB	2.20	2.42	105/M1	ST 10	0.42
252	18	MBCE-I	1	A-6			MSICL	CL-ML	15°	35°	50°	10-15°	30°	TNT	7.08	7.08	155/M107	STB 11	-0.56
253	18	MBCE-I	1	B-11			MSICL	CL-ML	15°	35°	50°	10-15°	30°	COMPB	2.20	2.42	105/M1	STB 10	-0.57
254	18	MBCE-I	1	B-8			MSICL	CL-ML	15°	35°	50°	10-15°	30°	COMPB	2.20	2.42	105/M1	STB 10	-0.57
255	18	MBCE-I	1	B-9			MSICL	CL-ML	15°	35°	50°	10-15°	30°	COMPB	2.20	2.42	105/M1	STB 10	-0.57
256	18	MBCE-I	1	A-9			MSICL	CL-ML	15°	35°	50°	10-15°	30°	TNT	7.08	7.08	155/M107	STB 15	-0.78
257	18	MBCE-I	1	B-2			MSICL	CL-ML	15°	35°	50°	10-15°	30°	COMPB	2.20	2.42	105/M1	STB 20	-0.88
258	18	MBCE-I	1	B-3			MSICL	CL-ML	15°	35°	50°	10-15°	30°	COMPB	2.20	2.42	105/M1	STB 20	-0.88
259	18	MBCE-I	1	B-5			MSICL	CL-ML	15°	35°	50°	10-15°	30°	COMPB	2.20	2.42	105/M1	STB 20	-0.88
260	18	MBCE-I	1	A-5			MSICL	CL-ML	15°	35°	50°	10-15°	30°	TNT	7.08	7.08	155/M107	STB 20	-1.00
261	18	MBCE-I	1	A-8			MSICL	CL-ML	15°	35°	50°	10-15°	30°	TNT	7.08	7.08	155/M107	STB 20	-1.00
262	18	MBCE-I	1	A-2			MSICL	CL-ML	15°	35°	50°	10-15°	30°	TNT	7.08	7.08	155/M107	STB 20	-1.00
263	18	MBCE-I	1	E-10			MSICL	CL-ML	15°	35°	50°	10-15°	30°	C4	2.45	2.18			-1.00
264	18	MBCE-I	1	E-2			MSICL	CL-ML	15°	35°	50°	10-15°	30°	C4	7.30	6.95			-1.00
265	18	MBCE-I	1	E-5			MSICL	CL-ML	15°	35°	50°	10-15°	30°	C4	2.31	2.18			-1.00
266	18	MBCE-I	1	E-8			MSICL	CL-ML	15°	35°	50°	10-15°	30°	C4	7.30	6.94			-1.00
267	18	MBCE-I	1	C-9			MSICL	CL-ML	15°	35°	50°	10-15°	30°	TNT	3.54	3.54	4.2/M329	STB 60	-1.88
268	18	MBCE-I	1	C-3			MSICL	CL-ML	15°	35°	50°	10-15°	30°	TNT	3.54	3.54	4.2/M329	STB 60	-1.88
269	18	MBCE-I	1	C-12			MSICL	CL-ML	15°	35°	50°	10-15°	30°	TNT	3.54	3.54	4.2/M329	STB 60	-1.88
270	18	MBCE-I	1	C-5			MSICL	CL-ML	15°	35°	50°	10-15°	30°	TNT	3.54	3.54	4.2/M329	STB 60	-2.27
271	18	MBCE-I	1	C-8			MSICL	CL-ML	15°	35°	50°	10-15°	30°	TNT	3.54	3.54	4.2/M329	STB 60	-2.27
272	18	MBCE-I	1	C-2			MSICL	CL-ML	15°	35°	50°	10-15°	30°	TNT	3.54	3.54	4.2/M329	STB 60	-2.27

(Continued)

Table 5 (Continued)

WHITE SANDS MISSILE RANGE,NM, (QUEEN 15 AREA) MOIST SILTY CLAY

ROW	SHOT ID	re,m	de,m	Ve,m3	rt,m	dt,m	Vt,m3	Ve'm3/We	Va/Wn	Vt'm3/kg	Vt/Wn	Ve,m3	We,kg	Ejec Cal	D C Obs	Ks	V/C Obs
227	C-1	0.35	0.18	3.12E-2*				1.04E-2*	7.88E-3*			1.85E-2*		ve=0.53ve		0.46/-	
228	C-4	0.45	0.25	7.18E-2*				2.38E-2*	1.76E-2*			3.78E-2*		ve=0.53ve		0.46/-	
229	C-6	0.40	0.25	5.86E-2*				1.89E-2*	1.39E-2*			2.99E-2*		ve=0.53ve		0.46/-	
230	C-10	0.30	0.13	1.85E-2*				5.49E-3*	4.06E-3*			8.74E-3*		ve=0.53ve		0.46/-	
231	C-7	0.30	0.18	2.04E-2*				6.79E-3*	5.01E-3*			1.08E-2*		ve=0.53ve		0.46/-	
232	A-13	1.00	0.58	7.92E-1*				1.44E-1*	9.00E-2*			4.20E-1*		ve=0.53ve		0.46/-	
233	A-14	0.85	0.60	6.38E-1*				1.16E-1*	7.25E-2*			3.38E-1*		ve=0.53ve		0.46/-	
234	A-15	0.85	0.60	6.38E-1*				1.16E-1*	7.25E-2*			3.38E-1*		ve=0.53ve		0.46/-	
235	A-1	1.00	0.45	6.36E-1*				1.16E-1*	7.23E-2*			3.37E-1*		ve=0.53ve		0.46/-	
236	A-4	1.05	0.40	6.23E-1*				1.13E-1*	7.08E-2*			3.30E-1*		ve=0.53ve		0.46/-	
237	E-8	0.80	0.35	1.78E-1*				5.05E-2*	3.58E-2*			1.18E-1*		ve=0.86ve		0.46/-	
238	E-1	0.90	0.52	5.88E-1*				7.16E-2*	3.99E-2*			3.87E-1*		ve=0.86ve		0.46/-	
239	E-11	0.45	0.25	7.18E-2*				4.49E-2*	3.98E-2*			4.85E-2*		ve=0.86ve		0.46/-	
240	E-3	0.90	0.50	5.73E-1*				7.03E-2*	3.92E-2*			3.72E-1*		ve=0.86ve		0.46/-	
241	E-4	0.55	0.29	1.20E-1*				3.40E-2*	2.40E-2*			8.32E-2*		ve=0.86ve		0.46/-	
242	B-1	0.70	0.28	1.84E-1*				9.00E-2*	7.27E-2*			1.03E-1*		ve=0.53ve		0.46/-	
243	B-4	0.80	0.57	5.18E-1*				2.39E-1*	1.93E-1*			2.73E-1*		ve=0.53ve		0.46/-	
244	B-6	0.80	0.27	2.44E-1*				1.13E-1*	9.14E-2*			1.28E-1*		ve=0.53ve		0.46/-	
245	A-7	1.05	0.55	8.57E-1*				1.56E-1*	9.74E-2*			4.54E-1*		ve=0.53ve		0.46/-	
246	A-12	1.10	0.83	1.42*				2.59E-1*	1.61E-1*			7.53E-1*		ve=0.53ve		0.46/-	
247	A-11	1.00	0.70	9.80E-1*				1.81E-1*	1.12E-1*			5.25E-1*		ve=0.53ve		0.46/-	
248	A-10	1.00	0.65	9.18E-1*				1.68E-1*	1.04E-1*			4.87E-1*		ve=0.53ve		0.46/-	
249	B-10	0.65	0.29	1.67E-1*				7.74E-2*	6.25E-2*			8.85E-2*		ve=0.53ve		0.46/-	
250	B-12	0.65	0.30	1.78E-1*				8.30E-2*	6.70E-2*			9.40E-2*		ve=0.53ve		0.46/-	
251	B-7	0.65	0.33	3.37E-1*				1.56E-1*	1.26E-1*			1.78E-1*		ve=0.53ve		0.46/-	
252	A-9	1.10	0.80	1.03*				1.87E-1*	1.17E-1*			5.46E-1*		ve=0.53ve		0.46/-	
253	B-11	0.85	0.45	5.74E-1*				2.66E-1*	2.15E-1*			3.04E-1*		ve=0.53ve		0.46/-	
254	B-8	1.00	0.50	7.07E-1*				3.28E-1*	2.65E-1*			3.75E-1*		ve=0.53ve		0.46/-	
255	B-9	0.85	0.48	4.90E-1*				2.27E-1*	1.84E-1*			2.60E-1*		ve=0.53ve		0.46/-	
256	A-8	1.25	0.80	1.77*				3.22E-1*	2.01E-1*			9.38E-1*		ve=0.53ve		0.46/-	
257	B-2	0.85	0.50	5.11E-1*				2.37E-1*	1.91E-1*			2.71E-1*		ve=0.53ve		0.46/-	
258	B-3	1.00	0.72	1.02*				4.72E-1*	3.82E-1*			5.41E-1*		ve=0.53ve		0.46/-	
259	B-5	1.00	0.51	7.21E-1*				3.34E-1*	2.70E-1*			3.82E-1*		ve=0.53ve		0.46/-	
260	A-5	1.15	0.75	1.40*				2.55E-1*	1.59E-1*			7.42E-1*		ve=0.53ve		0.46/-	
261	A-6	1.20	0.70	1.43*				2.61E-1*	1.62E-1*			7.58E-1*		ve=0.53ve		0.46/-	
262	A-2	1.20	0.80	1.83*				3.33E-1*	2.08E-1*			9.70E-1*		ve=0.53ve		0.46/-	
263	E-10	0.55	0.45	1.82E-1*				9.78E-2*	6.07E-2*			1.25E-1*		ve=0.86ve		0.46/-	
264	E-2	1.05	0.67	1.04*				1.93E-1*	1.21E-1*			6.76E-1*		ve=0.86ve		0.46/-	
265	E-5	0.75	0.45	3.58E-1*				1.81E-1*	1.50E-1*			2.33E-1*		ve=0.86ve		0.46/-	
266	E-6	1.05	0.63	9.82E-1*				1.81E-1*	1.14E-1*			6.38E-1*		ve=0.86ve		0.46/-	
267	C-9	1.10	0.75	1.29*				4.27E-1*	3.14E-1*			6.76E-1*		ve=0.86ve		0.46/-	
268	C-8	1.10	0.65	1.11*				3.70E-1*	2.73E-1*			5.88E-1*		ve=0.86ve		0.46/-	
269	C-12	0.95	0.68	8.68E-1*				2.88E-1*	2.13E-1*			4.60E-1*		ve=0.86ve		0.46/-	
270	C-5	1.10	0.88	1.51*				5.03E-1*	3.71E-1*			8.00E-1*		ve=0.86ve		0.46/-	
271	C-3	1.30	0.85	2.27*				7.55E-1*	5.58E-1*			1.20*		ve=0.86ve		0.46/-	
272	C-2	1.00	0.68	9.61E-1*				3.18E-1*	2.35E-1*			5.09E-1*		ve=0.86ve		0.46/-	

(Continued)

Table 5 (Continued)

ROW	REF/SR	TEST P/S	A OBS	SHOT ID	X COORD	Y COORD	SOIL DES	USCS	SA.%	SI.%	CL.%	MC.%	DESA.%	TYPE CH	CH WT.kg	E TNT.kg	TM C/M	ND D/A	H/DOB.R
273	18/30	MBCE-II	1	D1	40.00	20.00	SaSiCl	CL°	30°	10°	60°	20	40°	TNT	1.98	1.98	122/USSR	ST 20	1.15
274	18/30	MBCE-II	1	D2	40.00	10.00	SaSiCl	CL°	30°	10°	60°	20	40°	TNT	1.98	1.98	122/USSR	ST 20	1.15
275	18/30	MBCE-II	1	D3	40.00	0.00	SaSiCl	CL°	30°	10°	60°	21	40°	TNT	1.98	1.98	122/USSR	ST 20	1.15
276	18/30	MBCE-II	1	D5	30.00	20.00	SaSiCl	CL°	30°	10°	60°	20	40°	TNT	1.98	1.98	122/USSR	STB 20	1.15
277	18/30	MBCE-II	1	E4	90.00	20.00	SaSiCl	CL°	30°	10°	60°	21	40°	TNT	6.40	6.40	152/USSR	ST 20	1.11
278	18/30	MBCE-II	1	E1	80.00	20.00	SaSiCl	CL°	30°	10°	60°	20	40°	TNT	6.40	6.40	152/USSR	ST 20	1.11
279	18/30	MBCE-II	1	E2	80.00	30.00	SaSiCl	CL°	30°	10°	60°	18	35°	TNT	6.40	6.40	152/USSR	ST 20	1.11
280	18/30	MBCE-II	1	E3	80.00	40.00	SaSiCl	CL°	30°	10°	60°	16	30°	TNT	6.40	6.40	152/USSR	ST 20	1.11
281	18/30	MBCE-II	1	A1	75.00	20.00	SaSiCl	CL°	30°	10°	60°	20	40°	TNT	7.08	7.08	155/M107	ST 20	1.04
282	18/30	MBCE-II	1	A2	70.00	10.00	SaSiCl	CL°	30°	10°	60°	20	40°	TNT	7.08	7.08	155/M107	ST 20	1.04
283	18/30	MBCE-II	1	A3	70.00	0.00	SaSiCl	CL°	30°	10°	60°	24	45°	TNT	7.08	7.08	155/M107	ST 20	1.04
284	18/30	MBCE-II	1	C1	80.00	20.00	SaSiCl	CL°	30°	10°	60°	23	45°	C4	12.00	11.40			1.02
285	18/30	MBCE-II	1	C2	80.00	10.00	SaSiCl	CL°	30°	10°	60°	23	45°	C4	12.00	11.40			1.02
286	18/30	MBCE-II	1	C3	80.00	10.00	SaSiCl	CL°	30°	10°	60°	18	40°	C4	12.00	11.40			1.02
287	18/30	MBCE-II	1	B1	50.00	20.00	SaSiCl	CL°	30°	10°	60°	17	35°	COMPB	2.20	2.42	105/M1	ST 20	0.89
288	18/30	MBCE-II	1	B2	50.00	10.00	SaSiCl	CL°	30°	10°	60°	18	40°	COMPB	2.20	2.42	105/M1	ST 20	0.89
289	18/30	MBCE-II	1	B3	50.00	0.00	SaSiCl	CL°	30°	10°	60°	28	50°	COMPB	2.20	2.42	105/M1	ST 20	0.89
290	18/30	MBCE-II	1	B4	10.00	20.00	SaSiCl	CL°	30°	10°	60°	15	30°	COMPB	2.20	2.42	105/M1	STB 20	-0.89
291	18/30	MBCE-II	1	B5	20.00	10.00	SaSiCl	CL°	30°	10°	60°	12	20°	COMPB	2.20	2.42	105/M1	STB 20	-0.89
292	18/30	MBCE-II	1	B7	20.00	0.00	SaSiCl	CL°	30°	10°	60°	20	40°	COMPB	2.20	2.42	105/M1	STB 20	-0.89
293	18/30	MBCE-II	1	A6	80.00	0.00	SaSiCl	CL°	30°	10°	60°	20	40°	TNT	7.08	7.08	155/M107	STB 20	-1.01
294	18/30	MBCE-II	1	A4	110.00	20.00	SaSiCl	CL°	30°	10°	60°	20	40°	TNT	7.08	7.08	155/M107	STB 20	-1.01
295	18/30	MBCE-II	1	A5	80.00	10.00	SaSiCl	CL°	30°	10°	60°	18	30°	TNT	7.08	7.08	155/M107	STB 20	-1.01
296	18/30	MBCE-II	1	C4	0.00	20.00	SaSiCl	CL°	30°	10°	60°	17	35°	C4	6.60	8.44			-1.02
297	18/30	MBCE-II	1	C5	30.00	10.00	SaSiCl	CL°	30°	10°	60°	17	35°	C4	6.60	8.44			-1.02
298	18/30	MBCE-II	1	E5	110.00	10.00	SaSiCl	CL°	30°	10°	60°	17	35°	TNT	6.40	6.40	152/USSR	STB 20	-1.11
299	18/30	MBCE-II	1	E6	140.00	10.00	SaSiCl	CL°	30°	10°	60°	18	30°	TNT	6.40	6.40	152/USSR	STB 20	-1.11
300	18/30	MBCE-II	1	E7	130.00	10.00	SaSiCl	CL°	30°	10°	60°	16	30°	TNT	6.40	6.40	152/USSR	STB 20	-1.11
301	18/30	MBCE-II	1	E8	130.00	0.00	SaSiCl	CL°	30°	10°	60°	17	35°	TNT	6.40	6.40	152/USSR	STB 20	-1.11
302	18/30	MBCE-II	1	D6	15.00	11.00	SaSiCl	CL°	30°	10°	60°	15	30°	TNT	1.98	1.98	122/USSR	STB 20	-1.16
303	18/30	MBCE-II	1	D7	30.00	0.00	SaSiCl	CL°	30°	10°	60°	17	30°	TNT	1.98	1.98	122/USSR	STB 20	-1.15
304	18/30	MBCE-II	1	D8	20.00	20.00	SaSiCl	CL°	30°	10°	60°	15	30°	TNT	1.98	1.98	122/USSR	STB 20	-1.15
305	18/30	MBCE-II	1	D4	110.00	20.00	SaSiCl	CL°	30°	10°	60°	18	35°	TNT	1.98	1.98	122/USSR	STB 20	-1.16

FORT BENNING,GA. (COOLIDGE MORTAR RANGE) MOIST SILTY SAND

ROW	REF/SR	TEST P/S	A OBS	SHOT ID	X COORD	Y COORD	SOIL DES	USCS	SA.%	SI.%	CL.%	MC.%	DESA.%	TYPE CH	CH WT.kg	E TNT.kg	TM C/M	ND D/A	H/DOB.R
306	15	PBT	1	S-7			MSiSand	SM°	60°	30°	10°	5°	7°	TNT	3.54	3.54	4.2/M329	ST 60	2.40
307	15	PBT	1	S-2			MSiSand	SM°	60°	30°	10°	5°	7°	COMPB	0.86	1.06	81/M374	ST 60	2.10
308	15	PBT	1	S-5			MSiSand	SM°	60°	30°	10°	5°	7°	COMPB	0.86	1.06	81/M374	1/36UR60	0.80
309	15	PBT	1	S-9			MSiSand	SM°	60°	30°	10°	5°	7°	COMPB	0.86	1.06	81/M374	1/36UR45	0.80
310	15	PBT	1	S-3			MSiSand	SM°	60°	30°	10°	5°	7°	COMPB	0.86	1.06	81/M374	S 60	0.00
311	15	PBT	1	S-4			MSiSand	SM°	60°	30°	10°	5°	7°	COMPB	0.86	1.06	81/M374	S 60	0.00
312	15	PBT	1	S-13			MSiSand	SM°	60°	30°	10°	5°	7°	COMPB	2.30	2.53	105/M1	ST 15	0.80
313	15	PBT	1	S-6			MSiSand	SM°	60°	30°	10°	5°	7°	COMPB	2.30	2.53	105/M1	ST 15	0.80
314	15	PBT	1	S-10			MSiSand	SM°	60°	30°	10°	5°	7°	COMPB	2.30	2.53	105/M1	S 15	0.00
315	15	PBT	1	S-11			MSiSand	SM°	60°	30°	10°	5°	7°	COMPB	2.30	2.53	105/M1	S 15	0.00
316	15	PBT	1	S-12			MSiSand	SM°	60°	30°	10°	5°	7°	COMPB	2.30	2.53	105/M1	S 90	0.00
317	15	PBT	1	S-8			MSiSand	SM°	60°	30°	10°	5°	7°	COMPB	2.30	2.53	105/M1	S 90	0.00

(Continued)

Table 5 (Continued)

ROW	SHOT ID	re,m	de,m	Ve,m3	rt,m	dt,m	Vt,m3	Ve'm3/We	Ve/Wn	Vt'm3/kg	Vt/Wn	Ve,m3	We,kg	Ejec Cal	D C Obs	Ke	V/C Obs
273	D1	0.78	0.37	3.69E-1				2.00E-1	1.69E-1			1.92E-1		ve=0.53ve		0.50/-	
274	D2	0.83	0.30	3.25E-1				1.80E-1	1.28E-1			1.72E-1		ve=0.53ve		0.50/-	
275	D3	1.02	0.48	7.88E-1				4.35E-1	3.04E-1			4.18E-1		ve=0.53ve		0.50/-	
276	D5	1.02	0.38	6.41E-1				3.54E-1	2.47E-1			3.40E-1		ve=0.53ve		0.53/-	
277	E4	1.04	0.37	7.60E-1				1.49E-1	8.51E-2			4.03E-1		ve=0.53ve		0.80/-	
278	E1	0.98	0.43	7.53E-1				1.48E-1	8.42E-2			3.99E-1		ve=0.53ve		0.80/-	
279	E2	1.00	0.41	7.78E-1				1.53E-1	8.75E-2			4.13E-1		ve=0.53ve		0.80/-	
280	E3	1.10	0.31	7.13E-1				1.40E-1	8.02E-2			3.78E-1		ve=0.53ve		0.80/-	
281	A1	1.22	0.52	1.15				2.08E-1	1.44E-1			6.10E-1		ve=0.53ve		0.47/-	
282	A2	1.13	0.55	1.05				1.91E-1	1.31E-1			5.56E-1		ve=0.53ve		0.47/-	
283	A3	1.20	0.53	1.14				2.08E-1	1.43E-1			6.04E-1		ve=0.53ve		0.47/-	
284	C1	1.08	0.68	1.14				1.37E-1	7.85E-2			7.52E-1		ve=0.88ve		0.45/-	
285	C2	1.24	0.71	1.54				1.85E-1	1.03E-1			1.02		ve=0.88ve		0.45/-	
286	C3	0.85	0.88	8.68E-1				1.04E-1	5.83E-2			6.73E-1		ve=0.88ve		0.45/-	
287	B1	0.54	0.29	2.07E-1				9.58E-2	7.75E-2			1.10E-1		ve=0.53ve		0.78/-	
288	B2	0.77	0.28	4.07E-1				1.88E-1	1.52E-1			2.16E-1		ve=0.53ve		0.78/-	
289	B3	0.68	0.31	3.31E-1				1.54E-1	1.24E-1			1.75E-1		ve=0.53ve		0.78/-	
290	B4	1.14	0.68	8.35E-1				3.42E-1	2.78E-1			4.43E-1		ve=0.53ve		0.31/-	
291	B6	1.54	0.47	1.08				5.05E-1	4.08E-1			5.78E-1		ve=0.53ve		0.31/-	
292	B7	1.18	0.73	9.83E-1				4.48E-1	3.61E-1			5.10E-1		ve=0.53ve		0.31/-	
293	A6	1.04	0.54	1.37				2.50E-1	1.58E-1			7.28E-1		ve=0.53ve		0.74/-	
294	A4	1.58	0.80	4.58				8.31E-1	5.18E-1			2.42		ve=0.53ve		0.74/-	
295	A5	0.98	0.70	1.21				2.21E-1	1.38E-1			6.41E-1		ve=0.53ve		0.74/-	
296	C4	1.43	0.87	2.52				4.88E-1	3.18E-1			1.74		ve=0.88ve		0.45/-	
297	C5	1.48	0.88	3.04				6.01E-1	3.84E-1			2.10		ve=0.88ve		0.45/-	
298	E5	1.30	0.78	4.20				8.25E-1	5.25E-1			2.23		ve=0.53ve		1.00/-	
299	E6	1.38	0.64	3.72				6.61E-1	4.20E-1			1.97		ve=0.53ve		1.00/-	
300	E7	1.05	0.63	2.19				4.48E-1	2.84E-1			1.16		ve=0.53ve		1.00/-	
301	E8	1.28	0.88	3.45				7.05E-1	4.48E-1			1.83		ve=0.53ve		1.00/-	
302	D8	1.08	0.38	7.14E-1				3.86E-1	3.34E-1			3.78E-1		ve=0.53ve		0.53/-	
303	D7	1.12	0.65	1.35				7.45E-1	6.31E-1			7.18E-1		ve=0.53ve		0.53/-	
304	D6	1.24	0.77	1.98				1.08	9.18E-1			1.04E-1		ve=0.53ve		0.53/-	
305	D4	1.08	0.60	1.12				6.18E-1	5.23E-1			5.94E-1		ve 0.53ve		0.53/-	

FORT BENNING,GA. (COOLIDGE MORTAR RANGE) MOIST SILTY SAND

ROW	SHOT ID	re,m	de,m	Ve,m3	rt,m	dt,m	Vt,m3	Ve'm3/We	Ve/Wn	Vt'm3/kg	Vt/Wn	Ve,m3	We,kg	Ejec Cal	D C Obs	Ke	V/C Obs
306	S-7	0.70	0.21	6.78E-2				2.28E-2	1.67E-2			3.60E-2		ve=0.53ve		0.21/-	
307	S-2	0.58	0.23	1.20E-1				1.15E-1	1.14E-1			6.36E-2		ve=0.53ve		0.53/-	
308	S-5	0.43	0.27	8.31E-2				7.98E-2	7.67E-2			4.40E-2		ve=0.53ve		0.53/-	
309	S-6	0.58	0.24	1.34E-1				1.29E-1	1.27E-1			7.10E-2		ve=0.53ve		0.21/-	
310	S-3	0.48	0.29	1.16E-1				1.11E-1	1.10E-1			6.15E-2		ve=0.53ve		0.53/-	
311	S-4	0.48	0.27	1.08E-1				1.04E-1	1.02E-1			5.72E-2		ve=0.53ve		0.53/-	
312	S-13	0.88	0.20	9.58E-2				4.28E-2	3.42E-2			5.08E-2		ve=0.53ve		0.36/-	
313	S-8	0.62	0.27	1.14E-1				5.09E-2	4.08E-2			6.04E-2		ve=0.53ve		0.36/-	
314	S-10	0.88	0.47	4.00E-1				1.78E-1	1.49E-1			2.12E-1		ve=0.53ve		0.36/-	
315	S-11	0.85	0.38	3.02E-1				1.34E-1	1.08E-1			1.60E-1		ve=0.53ve		0.36/-	
316	S-12	0.93	0.48	4.37E-1				1.95E-1	1.56E-1			2.32E-1		ve=0.53ve		0.36/-	
317	S-9	1.08	0.58	7.44E-1				3.32E-1	2.85E-1			3.94E-1		ve=0.53ve		0.36/-	

(Continued)

Table 5 (Continued)

ROW	REF/SR	TEST P/S	A OBS	SHOT ID	X COORD	Y COORD	SOIL DES	USCS	SA,%	SI,%	CL,%	MC,%	DESA,%	TYPE CH	CH WT,kg	E TNT,kg	TM C/M	MD	D/A	H/DOB,R
318	27	BOT	1	10			SaClSi	MH	27	46	27	35	70*	TNT	6.62	6.62	155/M107	ST	30	1.60
319	27	BOT	1	14			SaClSi	ML	18	64	18	35	70*	TNT	6.62	6.62	155/M107	ST	30	1.60
320	27	BOT	1	15			SaClSi	MH	23	47	30	35	70*	TNT	6.62	6.62	155/M107	ST	30	1.60
321	27	BOT	1	18			SaClSi	MH	26	55	19	43	75*	TNT	6.62	6.62	155/M107	ST	30	1.60
322	27	BOT	1	19			SaClSi	CL	19	36	45	35	70*	TNT	6.62	6.62	155/M107	ST	30	1.60
323	27	BOT	1	20			SaClSi	CL	19	19	62	52	78*	TNT	6.62	6.62	155/M107	ST	30	1.60
324	27	BOT	1	36			SaClSi	MH	24	57	19	26	50*	TNT	6.62	6.62	155/M107	ST	30	1.60
325	27	BOT	1	37			SaClSi	MH	19	66	15	28	80*	TNT	6.62	6.62	155/M107	ST	30	1.60
326	27	BOT	1	38			SaClSi	MH	27	[illegible]	17	38	70*	TNT	6.62	6.62	155/M107	ST	30	1.60
327	27	BOT	1	45			SaClSi	MH	18	[illegible]	17	35	70*	TNT	6.62	6.62	155/M107	ST	30	1.60
328	27	BOT	1	48			SaClSi	MH	15	[illegible]	38	30	60*	TNT	6.62	6.62	155/M107	ST	30	1.60
329	27	BOT	1	49			SaClSi	MH	22	56	22	35	70*	TNT	6.62	6.62	155/M107	ST	30	1.60
330	27	BOT	1	55			SaClSi	MH	24	59	17	37	70*	TNT	6.62	6.62	155/M107	ST	30	1.60
331	27	BOT	1	58			SaClSi	MH	22	63	15	28	58*	TNT	6.62	6.62	155/M107	ST	30	1.60
332	27	BOT	1	9			SaClSi	MH	28	48	24	35	70*	TNT	6.62	6.62	155/M107	ST	30	1.60
333	27	BOT	1	8			SaClSi	CH	22	30	48	36	70*	COMPB	2.30	2.53	105/M1	ST	30	1.30
334	27	BOT	1	7			SaClSi	MH	23	62	15	36	70*	COMPB	2.30	2.53	105/M1	ST	30	1.30
335	27	BOT	1	6			SaClSi	MH	25	57	18	38	70*	COMPB	2.30	2.53	105/M1	ST	30	1.30
336	27	BOT	1	54			SaClSi	MH	24	54	22	28	58*	COMPB	2.30	2.53	105/M1	ST	30	1.30
337	27	BOT	1	53			SaClSi	MH	20	60	20	36	70*	COMPB	2.30	2.53	105/M1	ST	30	1.30
338	27	BOT	1	41			SaClSi	MH	27	56	17	30	80*	COMPB	2.30	2.53	105/M1	ST	30	1.30
339	27	BOT	1	11			SaClSi	ML	27	57	16	36	70*	COMPB	2.30	2.53	105/M1	ST	30	1.30
340	27	BOT	1	12			SaClSi	MH	25	42	33	36	70*	COMPB	2.30	2.53	105/M1	ST	30	1.30
341	27	BOT	1	13			SaClSi	ML	28	57	15	35	70*	COMPB	2.30	2.53	105/M1	ST	30	1.30
342	27	BOT	1	33			SaClSi	MH	9	47	44	40	70*	COMPB	2.30	2.53	105/M1	ST	30	1.30
343	27	BOT	1	34			SaClSi	ML	24	55	21	36	70*	COMPB	2.30	2.53	105/M1	ST	30	1.30
344	27	BOT	1	35			SaClSi	ML	25	54	21	35	70*	COMPB	2.30	2.53	105/M1	ST	30	1.30
345	27	BOT	1	39			SaClSi	MH	19	65	16	35	70*	COMPB	2.30	2.53	105/M1	ST	30	1.30
346	27	BOT	1	40			SaClSi	MH	22	56	22	36	70*	COMPB	2.30	2.53	105/M1	ST	30	1.30

TROPIC TEST CENTER (MINDI FARM AREA)

ROW	REF/SR	TEST P/S	A OBS	SHOT ID	X COORD	Y COORD	SOIL DES	USCS	SA,%	SI,%	CL,%	MC,%	DESA,%	TYPE CH	CH WT,kg	E TNT,kg	TM C/M	MD	D/A	H/DOB,R
347	27	BOT	1	57			SaSi	MH	33	64	3	61	85*	TNT	6.80	6.80				1.00
348	27	BOT	1	58			SaSi	MH	38	58	4	63	85*	TNT	6.80	6.80				1.00
349	27	BOT	1	59			SaSi	MH	44	52	4	65	85*	TNT	6.80	6.80				1.00
350	27	BOT	1	60			SaSi	MH	42	53	5	58	85*	TNT	6.80	6.80				1.00
351	27	BOT	1	64			SaSi	MH	34	61	5	68	85*	TNT	6.62	6.62	155/M107	ST	30	1.60
352	27	BOT	1	65			SaSi	MH	38	57	5	63	85*	TNT	6.62	6.62	155/M107	ST	30	1.60
353	27	BOT	1	66			SaSi	MH	38	58	4	68	85*	TNT	6.62	6.62	155/M107	ST	30	1.60
354	27	BOT	1	63			SaSi	MH	39	56	5	74	85*	COMPB	2.30	2.53	105/M1	ST	30	1.30
355	27	BOT	1	62			SaSi	MH	40	54	6	70	85*	COMPB	2.30	2.53	105/M1	ST	30	1.30
356	27	BOT	1	61			SaSi	MH	39	58	3	71	85*	COMPB	2.30	2.53	105/M1	ST	30	1.30

(Continued)

Table 5 (Continued)

ROW	SHOT ID	re.m	de.m	Ve.m3	rt.m	dt.m	Vt.m3	Ve'm3/We	Ve/Wn	Vt'm3/kg	Vt/Wn	Ve.m3	We.kg	Ejec Cal	D C Obs	Ks	V/C Des
318	10	1.05	0.27	3.40E-1				6.57E-2	5.14E-2			0.46*	721.26	D=81.47R-2.62	24/1		U/PHG(13)
319	14	1.18	0.30	5.00E-1				9.65E-2	6.12E-2			0.34*	527.89	D=1.96e-0.15R	405/10		U/GBG(7)
320	15	0.95	0.29	3.20E-1			0.50	6.18E-2	3.92E-2	7.54E-2	8.11E-2	0.47*	732.57	D=58.71R-2.50	887/10		U/PBG(7)
321	18	1.20	0.26	7.20E-1				1.39E-1	8.81E-2			0.21*	327.58	D=44.58R-2.75	123/2		U/GCG(33)
322	19	1.15	0.28	4.40E-1			0.49	8.48E-2	5.39E-2	7.39E-2	5.99E-1	0.15*	238.39	D=2.19e-0.24R	91/1		U/PCG(18)
323	20	1.30	0.32	7.60E-1				1.47E-1	9.30E-2			0.40*		ve=0.53ve			U/MLC
324	36	1.16	0.22	4.10E-1				7.91E-2	5.02E-2			0.049*	76.11	D=1.50e-0.34R	938/10		U/PBG(24)
325	37	1.25	0.23	6.50E-1				1.26E-1	7.96E-2			0.59*	924.15	D=33.18R-22.2	368/20		U/PCG(8)
326	38	1.25	0.29	6.60E-1			0.71	1.28E-1	8.07E-2	1.12E-1	9.09E-2	0.14*	221.38	D=3.38e-0.30R	93/5,10		U/PHG(18)
327	46	1.22	0.30	6.30E-1				1.22E-1	7.71E-2			0.42*	658.01	D=172.22R-3.28	843/10		U/GBG(3)
328	48	1.00	0.23	3.40E-1				6.57E-2	4.16E-2			0.12*	182.82	D=1.81e-0.23R	414/5		U/GHG(25)
329	49	1.20	0.27	5.70E-1			0.67	1.04E-1	6.16E-2	8.14E-2	8.60E-2	0.61*	953.73	D=19.73R-2.13	313/2		U/GCG(18)
330	55	0.90	0.21	2.20E-1				4.24E-2	2.69E-2			0.12*		ve=0.53ve	131/2		U/DLC
331	56	1.00	0.28	4.10E-1				7.91E-2	5.02E-2			0.22*		ve=0.53ve	524/10		U/DLC
332	9	1.32	0.29	6.70E-1				1.29E-1	8.20E-2			0.16*	247.91	D=3.70e-0.30R	308/2		U/GHG(20)
333	6	0.92	0.22	1.80E-1			0.26	9.02E-2	6.43E-2	1.03E-1	9.27E-2	0.04*	76.27	D=0.71e-0.24R	116/10		U/GCG(49)
334	7	0.88	0.18	1.70E-1				7.58E-2	6.07E-2			0.058*	98.72	D=1.91e-0.39	151/5		U/GHG(53)
335	8	0.92	0.23	2.40E-1				1.07E-1	8.57E-2			0.16*		D=14.14R-2.33			U/PHG(21)
336	54	0.80	0.22	1.90E-1				8.47E-2	6.79E-2			0.10*		ve=0.53ve	60/2		U/OLC
337	53	0.90	0.29	2.80E-1				1.25E-1	1.00E-1			0.15*		ve=0.53ve			U/OLC
338	41	0.75	0.21	1.70E-1				7.58E-2	6.07E-2			0.27*	414.33	D=43.74R-2.85	67/5		U/GHG(21)
339	11	1.08	0.18	3.70E-1			0.40	1.65E-1	1.32E-1	1.58E-1	1.43E-1	0.10*	157.25	D=7.67R-2.31	82/1		U/GBG(15)
340	12	0.88	0.22	2.00E-1				8.92E-2	7.14E-2			0.055*	86.08	D=1.50e-0.33R	262/1		U/PBG(3)
341	13	0.80	0.22	1.70E-1			0.24	7.58E-2	6.07E-2	9.48E-2	8.56E-2	0.16*	250.09	D=7.88R-2.21	80/5		U/PCG(28)
342	33	0.85	0.22	1.90E-1				8.47E-2	6.79E-2			0.087*	136.21	D=2.44e-0.33R	328/5		U/PBG(12)
343	34	0.80	0.21	1.60E-1				7.13E-2	5.71E-2			0.059*	80.54	D=0.61e-0.25R	58/1		U/PCG(30)
344	35	0.95	0.18	3.00E-1			0.34	1.34E-1	1.07E-1	1.34E-1	1.21E-1	0.082*	127.90	D=3.03e-0.38R			U/PHG(18)
345	39	0.82	0.18	2.00E-1				8.92E-2	7.14E-2			0.046*	71.56	D=0.82e-0.27R	210/5		U/GBG(35)
346	40	0.68	0.20	1.00E-1				4.46E-2	3.57E-2			0.10*	157.84	D=8.23R-2.44			U/GCG(23)

TROPIC TEST CENTER (MINDI FARM AREA)

ROW	SHOT ID	re.m	de.m	Ve.m3	rt.m	dt.m	Vt.m3	Ve'm3/We	Ve/Wn	Vt'm3/kg	Vt/Wn	Ve.m3	We.kg	Ejec Cal	D C Obs	Ks	V/C Des
347	57	1.00	0.54	0.72				1.36E-1	8.58E-2			2.05E-1	281.39	D=28.50R-2.836	1421/10		SS
348	58	0.95	0.38	0.30				5.66E-2	3.57E-2			5.75E-2	85.72	D=1.74e-0.35R	893/10		CS
349	59	1.00	0.43	0.38			0.53	7.17E-2	4.52E-2	7.78E-2	6.30E-2	1.73E-1	247.00	D=11.87R-2.302	424/5		HG
350	60	1.00	0.45	0.81				1.53E-1	9.63E-2			5.28E-1	783.40	D=58.50R-2.485	818/10		HG
351	64	0.90	0.50	7.00E-1				1.36E-1	8.57E-2			0.31*	448.80	D=3.26e-0.21R	128/1		U/GBG(18)
352	65	1.05	0.32	5.60E-1				1.08E-1	6.86E-2			0.33*	481.34	D=87.04R-2.84	98/2		U/GHG(17)
353	66	0.98	0.45	4.50E-1			0.63	8.69E-2	5.51E-2	8.50E-2	7.70E-2	0.47*	681.58	D=25.05R-2.23	487/2		U/GCG(8)
354	63	0.89	0.40	2.90E-1			0.33	1.30E-1	1.04E-1	1.30E-1	1.18E-1	0.053*	78.87	D=0.88e-0.27R	108/1		U/GHG(33)
355	62	0.85	0.23	2.40E-1				1.07E-1	8.57E-2			0.045*	64.85	D=1.41e-0.36R	122/5		U/GBG(32)
356	61	0.85	0.23	1.70E-1				7.58E-2	6.07E-2			0.13*	182.85	D=8.02R-2.21	1435/10		U/GCG(24)

(Continued)

Table 5 (Concluded)

ROW	REF/SR	TEST P/S	A OBS	SHOT ID	X COORD	Y COORD	SOIL DES	USCS	SA,%	SI,%	CL,%	MC,%	DESA,%	TYPE CH	CH WT,kg	E TNT,kg	TN C/N	NO D/A	H/DOB,R
357	27	SDT	1	32			FineSand	SP*	98	2	0	12	20*	TNT	6.80	6.80			1.00
358	27	SDT	1	31			FineSand	SP*	98	2	0	20	38*	TNT	6.80	6.80			1.00
359	27	SDT	1	30			FineSand	SP*	90	10	0	18	30*	TNT	6.80	6.80			1.00
360	27	SDT	1	29			FineSand	SP*	92	8	0	10	10*	TNT	6.80	6.80			1.00
361	27	SDT	1	28			FineSand	SP*	90	10	0	17	30*	TNT	6.80	6.80			1.00
362	27	SDT	1	27			FineSand	SP*	93	7	0	9	20*	TNT	6.80	6.80			1.00
363	27	SDT	1	26			FineSand	SP*	96	4	0	5	10*	TNT	6.80	6.80			1.00
364	27	SDT	1	25			FineSand	SP*	96	4	0	8	10*	TNT	6.80	6.80			1.00
365	27	SDT	1	24			FineSand	SP*	97	3	0	5	10*	TNT	6.80	6.80			1.00
366	27	SDT	1	21			FineSand	SP*	90	10	0	8	15*	TNT	6.80	6.80			1.00
367	27	SDT	1	22			FineSand	SP*	92	8	0	8	10*	TNT	6.80	6.80			1.00
368	27	SDT	1	23			FineSand	SP*	97	3	0	7	15*	TNT	6.80	6.80			1.00

ROW	SHOT ID	ra,m	da,m	Va,m3	rt,m	dt,m	Vt,m3	Va'm3/We	Va/Wn	Vt'm3/kg	Vt/Wn	Ve,m3	We,kg	Ejec Cal	D C Obs	Ks	V/C Des
357	32		0.29	2.40E-1				4.53E-2	2.86E-2			7.92E-2*		ve=0.33va			U/MMG
358	31		0.42	3.80E-1				7.36E-2	4.64E-2			1.29E-1*		ve=0.33va			U/MMG
359	30		0.39	2.90E-1				5.47E-2	3.45E-2			9.57E-2*		ve=0.33va			U/SO
360	29		0.39	3.50E-1				6.61E-2	4.16E-2			1.16E-1*		ve=0.33va			U/SMB
361	28		0.37	3.70E-1				6.96E-2	4.40E-2			1.22E-1*		ve=0.33va			U/SMB
362	27		0.27	2.00E-1				3.77E-2	2.38E-2			6.60E-2*		ve=0.33va			U/SO
363	26		0.29	3.00E-1				5.66E-2	3.57E-2			1.50E-1*		ve=0.50va			U/MD
364	25		0.24	1.70E-1				3.21E-2	2.02E-2			8.50E-2*		ve=0.50va			U/MD
365	24		0.37	2.40E-1				4.53E-2	2.86E-2			1.20E-1*		ve=0.50va			U/MBL
366	21		0.33	2.90E-1				5.47E-2	3.45E-2			1.46E-1*		ve=0.50va			U/MDS
367	22		0.30	3.40E-1				6.41E-2	4.04E-2			1.70E-1*		ve=0.50va			U/MDS
368	23		0.44	2.20E-1				4.16E-2	2.62E-2			1.10E-1*		ve=0.50va			U/MBL

(Sheet 7 of 7)

Table 6

Cratering Data from Battlefield-Induced Contamination Test III

WHITE SANDS MISSILE RANGE,NM, (OROGRANDE) SILTY SAND

ROW	REF/SR	TEST P/S	A OBS	SHOT ID	X COORD	Y COORD	SOIL DES	USCS	SA,%	SI,%	CL,%	MC,%	DESA,%	TYPE CH	CH WT,kg	E TNT,kg	TM C/M	MD D/A	H/DOB,R
369	55	BICTIII	1	1	37.00	100.00	SiSand	SM*	60*	35*	5*	3-13	20*	C4	4.54	4.31			1.00
370	55	BICTIII	1	2	42.40	100.00	SiSand	SM*	60*	35*	5*	3-13	20*	C4	4.54	4.31			1.00
371	55	BICTIII	1	3	58.80	100.00	SiSand	SM*	60*	35*	5*	3-13	20*	C4	4.54	4.31			1.00
372	55	BICTIII	1	4	64.50	100.00	SiSand	SM*	60*	35*	5*	3-13	20*	C4	4.54	4.31			1.00
373	55	BICTIII	1	5	92.00	100.00	SiSand	SM*	60*	35*	5*	3-13	20*	C4	1.70	1.62			1.00
374	55	BICTIII	1	6	100.00	100.00	SiSand	SM*	60*	35*	5*	3-13	20*	C4	1.70	1.62			1.00
375	55	BICTIII	1	7	108.00	100.00	SiSand	SM*	60*	35*	5*	3-13	20*	C4	1.70	1.62			1.00
376	55	BICTIII	1	8	121.00	100.00	SiSand	SM*	60*	35*	5*	3-13	20*	C4	1.70	1.62			1.00
377	55	BICTIII	1	9	130.70	100.00	SiSand	SM*	60*	35*	5*	3-13	20*	C4	4.54	4.31			1.00
378	55	BICTIII	1	10	170.20	100.00	SiSand	SM*	60*	35*	5*	3-13	20*	C4	1.70	1.62			1.00
379	55	BICTIII	1	11	176.20	100.00	SiSand	SM*	60*	35*	5*	3-13	20*	C4	1.70	1.62			-1.00
380	55	BICTIII	1	12	180.00	100.00	SiSand	SM*	60*	35*	5*	3-13	20*	C4	1.70	1.62			-1.00
381	55	BICTIII	1	13	185.00	100.00	SiSand	SM*	60*	35*	5*	3-13	20*	C4	1.70	1.62			-1.00
382	55	BICTIII	1	14	190.00	100.00	SiSand	SM*	60*	35*	5*	3-13	20*	C4	1.70	1.62			-1.00
383	55	BICTIII	1	15	195.00	100.00	SiSand	SM*	60*	35*	5*	3-13	20*	C4	4.54	4.31			1.00
384	55	BICTIII	1	16	200.30	100.00	SiSand	SM*	60*	35*	5*	3-13	20*	C4	4.54	4.31			1.00
385	55	BICTIII	1	17	210.00	100.00	SiSand	SM*	60*	35*	5*	3-13	20*	C4	4.54	4.31			-1.00
386	55	BICTIII	1	18	220.00	100.00	SiSand	SM*	60*	35*	5*	3-13	20*	C4	4.54	4.31			-1.00
387	55	BICTIII	1	19	230.00	100.00	SiSand	SM*	60*	35*	5*	3-13	20*	C4	4.54	4.31			-1.00
388	55	BICTIII	1	20	240.00	100.00	SiSand	SM*	60*	35*	5*	3-13	20*	C4	4.54	4.31			-1.00
389	55	BICTIII	1	21	250.00	100.00	SiSand	SM*	60*	35*	5*	3-13	20*	C4	12.50	11.90			1.00
390	55	BICTIII	1	22	255.00	100.00	SiSand	SM*	60*	35*	5*	3-13	20*	C4	12.50	11.90			1.00
391	55	BICTIII	1	23	260.00	100.00	SiSand	SM*	60*	35*	5*	3-13	20*	C4	12.50	11.90			1.00
392	55	BICTIII	1	24	270.00	100.00	SiSand	SM*	60*	35*	5*	3-13	20*	C4	12.50	11.90			-1.00
393	55	BICTIII	1	25	280.00	100.00	SiSand	SM*	60*	35*	5*	3-13	20*	C4	12.50	11.90			-1.00
394	55	BICTIII	1	26	290.00	100.00	SiSand	SM*	60*	35*	5*	3-13	20*	C4	12.50	11.90			-1.00

(Continued)

Table 6 (Concluded)

WHITE SANDS MISSILE RANGE,NM. (OROGRANDE) SILTY SAND

ROW	SHOT ID	ra,m	da,m	Va,m3	rt,m	dt,m	Vt,m3	Va'm3/Wa	Va/Wn	Vt'm3/kg	Vt/Wn	Ve,m3	We,kg	Ejec Cal	O C Obs	Ka	V/C Des
369	1	0.68	0.32	2.09E-1*	0.70	0.50	3.08E-1*	5.81E-2*	4.12E-2*	7.16E-2*	8.08E-2*	1.11E-1*		ve=0.87va+.08vt		0.45/0.40	
370	2	0.58	0.31	2.03E-1*				5.70E-2*	4.00E-2*			2.20E-1*	0.04	0=38.40R-2.863		0.45/-	
371	3	1.00	0.25	3.54E-1*				9.83E-2*	6.99E-2*			3.80E-2*		ve=1.08va		0.45/-	
372	4	0.82	0.40	2.17E-1*	0.90	0.46	4.66E-1*	6.08E-2*	4.28E-2*	1.08E-1*	9.23E-2*	1.70E-1*		ve=0.87va+0.08vt		0.45/0.40	
373	5	0.48	0.23	8.88E-2*	0.52	0.28	9.51E-2*	4.53E-2*	4.02E-2*	5.67E-2*	5.56E-2*	1.40E-1*	231.00	0-14.82R-2.687		0.45/0.40	
374	6	0.62	0.17	9.24E-2*				6.07E-2*	5.40E-2*			9.78E-2*		ve=1.06va		0.45/-	
375	7	0.52	0.17	8.50E-2*	0.80	0.26	1.18E-1*	4.27E-2*	3.80E-2*	7.28E-2*	6.90E-2*	5.08E-2*		ve=0.87va+0.08vt		0.45/0.40	
376	8	0.58	0.27	1.28E-1*	0.60	0.32	1.45E-1*	8.41E-2*	7.49E-2*	8.96E-2*	8.49E-2*	9.45E-2*		ve=0.87va+0.08vt		0.45/0.40	
377	9	0.70	0.38	2.83E-1*	0.75	0.47	3.32E-1*	7.38E-2*	5.18E-2*	7.70E-2*	6.55E-2*	2.00E-1*		ve=0.87va+0.08vt		0.45/0.40	
378	10	0.46	0.23	6.68E-2*				4.33E-2*	3.85E-2*			6.89E-2*		ve=1.08va		0.45/-	
379	11	0.58	0.24	1.14E-1*				7.50E-2*	6.67E-2*			5.70E-2*		ve=0.5va		0.45/-	
380	12	0.54	0.22	9.07E-2*				5.96E-2*	5.30E-2*			4.54E-2*		ve=0.5va		0.45/-	
381	13	0.64	0.24	9.90E-2*				6.51E-2*	5.79E-2*			4.95E-2*		ve=0.5va		0.45/-	
382	14	0.54	0.28	1.07E-1*				7.03E-2*	6.26E-2*			5.36E-2*		ve=0.5va		0.45/-	
383	15	0.62	0.27	1.47E-1*	0.65	0.36	1.81E-1*	4.12E-2*	2.90E-2*	4.43E-2*	3.77E-2*	1.10E-1*		ve=0.87+0.08vt		0.45/0.40	
384	16	0.68	0.35	1.66E-1*	0.75	0.42	2.97E-1*	4.66E-2*	3.27E-2*	6.89E-2*	5.86E-2*	1.30E-1*		ve=0.87+0.08vt		0.45/0.40	
385	17	0.66	0.41	2.53E-1*				7.10E-2*	5.00E-2*			1.30E-1*		ve=0.5va		0.45/-	
386	18	0.75	0.44	3.50E-1*				9.82E-2*	6.90E-2*			1.80E-1*		ve=0.5va		0.45/-	
387	19	0.82	0.46	4.66E-1*				1.31E-1*	9.19E-2*			2.30E-1*		ve=0.5va		0.45/-	
388	20	0.75	0.48	3.82E-1*				1.07E-1*	7.53E-2*			1.90E-1*		ve=0.5va		0.45/-	
389	21	0.75	0.46	3.66E-1*				4.26E-2*	2.34E-2*			3.90E-1*		ve=1.08va		0.45/-	
390	22	0.78	0.42	3.81E-1*				4.18E-2*	2.30E-2*			3.80E-1*		ve=1.08va		0.45/-	
391	23	0.84	0.47	4.89E-1*				5.44E-2*	2.89E-2*			5.00E-1*		ve=1.08va		0.45/-	
392	24	1.22	0.88	1.85*				2.14E-1*	1.18E-1*			9.20E-1*		ve=0.5va		0.45/-	
393	25	1.18	0.87	1.71*				1.99E-1*	1.09E-1*			8.60E-1*		ve=0.5va		0.45/-	
394	26	1.15	0.77	1.44*				1.67E-1*	9.19E-2*			7.20E-1*		ve=0.5va		0.45/-	

Table 7

Cratering Data from Dust Obscuration Tests I and II

DOT I EXPERIMENT FORT CARSON,CO. SANDY CLAY

ROW	REF/SR	TEST P/S	A OBS	SHOT ID	X COORD	Y COORD	SOIL DES	USCS	SA.%	SI.%	CL.%	MC.%	DESA.%	TYPE CH	CH WT.kg	E TNT.kg	TN C/M	MO D/A	H/DOB.R
395	25	DOTI	1	A1	0.00	94.50	SaCl	CL	35°	10°	55°	11.5	20-30°	C4	3.40	3.23			1.00
396	25	DOTI	1	A2	2.40	79.90	SaCl	CL	35°	10°	55°	13.1	20-30°	C4	3.40	3.23			1.00
397	25	DOTI	1	A3	-8.10	106.10	SaCl	CL	35°	10°	55°	10.4	20-30°	C4	3.40	3.23			1.00
398	25	DOTI	1	A4	79.10	85.10	SaCl	CL	35°	10°	55°	33.3	20-30°	C4	3.40	3.23			1.00
399	25	DOTI	1	A5	77.70	9.00	SaCl	CL	35°	10°	55°	26.7	30-40°	C4	3.40	3.23			1.00
400	25	DOTI	1	A6	89.70	98.80	SaCl	CL	35°	10°	55°	13.9	20-30°	C4	3.40	3.23			1.00
401	25	DOTI	1	A7	7.70	76.20	SaCl	CL	35°	10°	55°	13.0	20-30°	C4	3.40	3.23			1.00
402	25	DOTI	1	A8	0.80	83.50	SaCl	CL	35°	10°	55°	11.4	20-30°	C4	3.40	3.23			1.00
403	25	DOTI	1	A9	30.70	20.90	SaCl	CL	35°	10°	55°	9.3	15-25°	C4	3.40	3.23			1.00
404	25	DOTI	1	B1	88.30	5.20	SaCl	CL	35°	10°	55°	19.5	25-35°	C4	6.80	6.46			1.00
405	25	DOTI	1	B2	50.40	4.50	SaCl	CL	35°	10°	55°	22.0	25-35°	C4	6.80	6.46			1.00
406	25	DOTI	1	B3	-18.00	79.40	SaCl	CL	35°	10°	55°	13.3	20-30°	C4	6.80	6.46			1.00
407	25	DOTI	1	B5	37.90	16.50	SaCl	CL	35°	10°	55°	11.5	20-30°	C4	6.80	6.46			1.00
408	25	DOTI	1	B6	61.70	72.70	SaCl	CL	35°	10°	55°	13.1	20-30°	C4	6.80	6.46			1.00
409	25	DOTI	1	B7	80.90	69.10	SaCl	CL	35°	10°	55°	11.9	20-30°	C4	6.80	6.46			1.00
410	25	DOTI	1	B8	53.30	18.30	SaCl	CL	35°	10°	55°	12.4	20-30°	C4	6.80	6.46			1.00
411	25	DOTI	1	B9	89.90	-0.80	SaCl	CL	35°	10°	55°	12.9	20-30°	C4	6.80	6.46			1.00
412	25	DOTI	1	B10	43.50	17.80	SaCl	CL	35°	10°	55°	12.4	20-30°	C4	6.80	6.46			1.00
413	25	DOTI	1	B11	39.10	9.40	SaCl	CL	35°	10°	55°	11.9	20-30°	C4	6.80	6.46			1.00
414	25	DOTI	1	B12	85.00	-11.40	SaCl	CL	35°	10°	55°	12.1	20-30°	C4	6.80	6.46			-1.00
415	25	DOTI	1	B13	51.40	-11.50	SaCl	CL	35°	10°	55°	7.2	10-15°	C4	6.80	6.46			-1.00
416	25	DOTI	1	B15	36.10	2.80	SaCl	CL	35°	10°	55°	7-27	20-30°	C4	6.80	6.46			-1.00
417	25	DOTI	1	C1	57.00	14.30	SaCl	CL	35°	10°	55°	23.8	25-35°	C4	11.30	10.70			1.00
418	25	DOTI	1	C2	81.70	87.70	SaCl	CL	35°	10°	55°	11.2	20-30°	C4	11.30	10.70			1.00
419	25	DOTI	1	C3	90.90	42.10	SaCl	CL	35°	10°	55°	12.8	20-30°	C4	11.30	10.70			1.00
420	25	DOTI	1	C4	85.70	78.30	SaCl	CL	35°	10°	55°	13.5	20-30°	C4	11.30	10.70			1.00
421	25	DOTI	1	C5	90.90	71.00	SaCl	CL	35°	10°	55°	12.7	20-30°	C4	11.30	10.70			1.00
422	25	DOTI	1	C6	29.80	5.80	SaCl	CL	35°	10°	55°	13.8	20-30°	C4	11.30	10.70			1.00
423	25	DOTI	1	C7	57.20	3.10	SaCl	CL	35°	10°	55°	11.8	20-30°	C4	11.30	10.70			1.00
424	25	DOTI	1	C8	85.30	17.50	SaCl	CL	35°	10°	55°	12.1	20-30°	C4	11.30	10.70			1.00
425	25	DOTI	1	C9	76.70	-13.90	SaCl	CL	35°	10°	55°	11.7	20-30°	C4	11.30	10.70			1.00
426	25	DOTI	1	C10	10.20	23.50	SaCl	CL	35°	10°	55°	12.4	20-30°	C4	11.30	10.70			1.00

DOT II EXPERIMENT FORT CARSON,CO. SANDY CLAY-SANDY SILT

ROW	REF/SR	TEST P/S	A OBS	SHOT ID	X COORD	Y COORD	SOIL DES	USCS	SA.%	SI.%	CL.%	MC.%	DESA.%	TYPE CH	CH WT.kg	E TNT.kg	TN C/M	MO D/A	H/DOB.R
427	25	DOTII	1	1B(8)	-43.30	25.00	SaCl/SaSi	CL	30°	35°	35°	11.8	15-30°	C4	6.80	6.46			1.00
428	25	DOTII	1	2B(8)	-48.00	0.00	SaCl/SaSi	CL	30°	35°	35°	17.5	15-30°	C4	6.80	6.46			1.00
429	25	DOTII	1	3C(10)	-43.50	11.80	SaCl/SaSi	CL	30°	35°	35°	13.2	15-30°	C4	11.30	10.70			1.00
430	25	DOTII	1	4B(11)a	-18.70	48.40	SaCl/SaSi	CL	30°	35°	35°	11.8	15-30°	C4	6.80	6.46			1.00
431	25	DOTII	1	4B(11)b	-8.10	48.80	SaCl/SaSi	CL	30°	35°	35°	10.5	15-30°	C4	6.80	6.46			1.00
432	25	DOTII	1	5B(14)a	11.90	44.40	SaCl/SaSi	CL	30°	35°	35°	7.9	15-30°	C4	6.80	6.46			1.00
433	25	DOTII	1	5B(14)b	22.80	41.10	SaCl/SaSi	CL	30°	35°	35°	9.2	15-30°	C4	6.80	6.46			1.00
434	25	DOTII	1	5B(14)c	31.80	31.80	SaCl/SaSi	CL	30°	35°	35°	5.0	15-30°	C4	6.80	6.46			1.00
435	25	DOTII	1	6C(15)a	14.20	53.10	SaCl/SaSi	CL	30°	35°	35°	9.1	15-30°	C4	11.30	10.70			1.00
436	25	DOTII	1	6C(15)b	-0.90	51.00	SaCl/SaSi	CL	30°	35°	35°	9.3	15-30°	C4	11.30	10.70			1.00
437	25	DOTII	1	7C(16)	0.00	37.00	SaCl/SaSi	CL	30°	35°	35°	7.2-17.5	15-30°	C4	11.30	10.70			

(Continued)

Table 7 (Concluded)

DOT I EXPERIMENT SANDY CLAY

ROW	SHOT ID	re,m	de,m	Ve,m3	rt,m	dt,m	Vt,m3	Ve'm3/We	Ve/Wn	Vt'm3/kg	Vt/Wn	Ve,m3	We,kg	Ejec Cal	D C Obs	Ke	V/C Des
395	A1			1.18E-1			4.20E-1	4.26E-2	3.21E-2	1.30E-1	1.14E-1	1.04E-1*		ve=0.73vt-vfb			AZ(60-70)
396	A2			1.51E-1			4.93E-1	5.44E-2	4.10E-2	1.53E-1	1.34E-1	1.31E-1*		ve=0.73vt-vfb			AZ(60-70)
397	A3			6.50E-2			2.42E-1	2.34E-2	1.77E-2	7.49E-2	6.58E-2	5.81E-2*		ve=0.73vt-vfb			AZ(60-70)
398	A4			1.10E-1			2.04E-1	3.97E-2	2.99E-2	6.32E-2	5.54E-2	8.59E-2*		ve=0.73vt-vfb			AZ(60-70)
399	A5			9.50E-2			1.78E-1	3.42E-2	2.58E-2	5.51E-2	4.84E-2	7.43E-2*		ve=0.73vt-vfb			AZ(60-70)
400	A6			1.26E-1			3.63E-1	4.54E-2	3.42E-2	1.18E-1	1.04E-1	1.07E-1*		ve=0.73vt-vfb			AZ(60-70)
401	A7			1.40E-1			3.78E-1	5.04E-2	3.81E-2	1.17E-1	1.03E-1	1.16E-1*		ve=0.73vt-vfb			AZ(60-70)
402	A8			1.07E-1			1.61E-1	3.85E-2	2.91E-2	4.98E-2	4.38E-2	8.14E-2*		ve=0.73vt-vfb			AZ(60-70)
403	A9			1.72E-1			4.29E-1	6.21E-2	4.68E-2	1.33E-1	1.17E-1	1.41E-1*		ve=0.73vt-vfb			AZ(60-70)
404	B1			2.83E-1			7.60E-1	6.19E-2	3.31E-2	1.18E-1	8.44E-2	2.21E-1*		ve=0.73vt-vfb			AZ(60-70)
405	B2			2.24E-1			8.48E-1	4.42E-2	2.82E-2	1.31E-1	1.07E-1	2.01E-1*		ve=0.73vt-vfb			AZ(60-70)
406	B3			2.16E-1			7.38E-1	4.24E-2	2.70E-2	1.14E-1	9.28E-2	1.88E-1*		ve=0.73vt-vfb			AZ(60-70)
407	B5			1.25			2.38	2.46E-1	1.57E-1	3.68E-1	2.99E-1	9.80E-1*		ve=0.73vt-vfb			AZ(60-70)
408	B6			2.31E-1			1.28	4.56E-2	2.91E-2	1.96E-1	1.58E-1	2.30E-1*		ve=0.73vt-vfb			AZ(60-70)
409	B7			3.10E-1			1.01	6.12E-2	3.90E-2	1.56E-1	1.27E-1	2.38E-1*		ve=0.73vt-vfb			AZ(60-70)
410	B8			3.35E-1			9.30E-1	6.61E-2	4.21E-2	1.44E-1	1.17E-1	2.80E-1*		ve=0.73vt-vfb			AZ(60-70)
411	B9			2.21E-1			5.26E-1	4.36E-2	2.78E-2	8.10E-2	6.66E-2	1.80E-1*		ve=0.73vt-vfb			AZ(60-70)
412	B10			1.91E-1			8.76E-1	3.77E-2	2.40E-2	1.36E-1	1.10E-1	1.80E-1*		ve=0.73vt-vfb			AZ(60-70)
413	B11			1.43E-1			5.47E-1	2.82E-2	1.80E-2	8.47E-2	6.88E-2	1.29E-1*		ve=0.73vt-vfb			AZ(60-70)
414	B12			7.78E-1			1.87	1.54E-1	9.80E-2	2.89E-1	2.10E-1	6.34E-1*		ve=0.73vt-vfb			AZ(60-70)
415	B13			4.40E-1			2.01	8.68E-2	5.53E-2	3.11E-1	2.53E-1	4.15E-1*		ve=0.73vt-vfb			AZ(60-70)
416	B15			8.10E-1			1.83	1.59E-1	1.02E-1	2.83E-1	2.30E-1	7.20E-1*		ve=0.73vt-vfb			AZ(60-70)
417	C1			4.05E-1			8.93E-1	5.92E-2	3.34E-2	9.34E-2	6.42E-2	3.65E-1*		ve=0.73vt-vfb			AZ(60-70)
418	C2			4.40E-1			1.35	5.86E-2	3.17E-2	1.29E-1	8.71E-2	3.76E-1*		ve=0.73vt-vfb			AZ(60-70)
419	C3			5.10E-1			1.14	6.49E-2	3.67E-2	1.07E-1	8.20E-2	4.10E-1*		ve=0.73vt-vfb			AZ(60-70)
420	C4			4.18E-1			6.60E-1	5.32E-2	3.01E-2	6.07E-2	6.81E-2	3.39E-1*		ve=0.73vt-vfb			AZ(60-70)
421	C5			7.58E-1			1.58	9.62E-2	5.44E-2	1.48E-1	1.12E-1	6.03E-1*		ve=0.73vt-vfb			AZ(60-70)
422	C6			4.94E-1			1.29	6.15E-2	3.48E-2	1.20E-1	9.21E-2	4.01E-1*		ve=0.73vt-vfb			AZ(60-70)
423	C7			3.92E-1			1.88	4.98E-2	2.82E-2	1.74E-1	1.34E-1	3.80E-1*		ve=0.73vt-vfb			AZ(60-70)
424	C8			4.81E-1			1.60	6.12E-2	3.46E-2	1.50E-1	1.15E-1	4.18E-1*		ve=0.73vt-vfb			AZ(60-70)
425	C9			6.84E-1			1.33	8.69E-2	4.90E-2	1.24E-1	9.57E-2	5.45E-1*		ve=0.73vt-vfb			AZ(60-70)
426	C10			4.43E-1			1.34	5.63E-2	3.19E-2	1.25E-1	9.64E-2	3.77E-1*		ve=0.73vt-vfb			AZ(60-70)

DOT II EXPERIMENT SANDY CLAY-SANDY SILT

ROW	SHOT ID	re,m	de,m	Ve,m3	rt,m	dt,m	Vt,m3	Ve'm3/We	Ve/Wn	Vt'm3/kg	Vt/Wn	Ve,m3	We,kg	Ejec Cal	D C Obs	Ke	V/C Des
427	1B(8)	0.95	0.46	3.20E-1	1.00	0.53	4.80E-1	8.31E-2	4.03E-2	7.43E-2	6.04E-2	2.43E-1*		ve=0.73vt-vfb			AZ(60-70)
428	2B(8)	0.80	0.37	1.86E-1	0.85	0.40	2.64E-1	3.71E-2	2.30E-2	5.03E-2	3.10E-2	1.41E-1*		ve=0.73vt-vfb			AZ(60-70)
429	3C(10)	0.80	0.43	3.93E-1	1.00	0.58	6.17E-1	4.89E-2	2.83E-2	4.83E-1	3.72E-2	2.94E-1*		ve=0.73vt-vfb			AZ(60-70)
430	4B(11)a	0.80	0.38	2.49E-1	0.80	0.50	3.06E-1	4.78E-2	3.06E-2	4.78E-2	3.88E-2	1.81E-1*		ve=0.73vt-vfb			AZ(60-70)
431	4B(11)b	0.80	0.26	1.51E-1	0.80	0.42	2.98E-1	2.98E-2	1.90E-2	4.49E-2	3.62E-2	1.18E-1*		ve=0.73vt-vfb			AZ(60-70)
432	5B(14)a	0.75	0.42	1.96E-1	0.80	0.48	2.38E-1	3.88E-2	2.47E-2	3.58E-2	2.96E-2	1.46E-1*		ve=0.73vt-vfb			AZ(60-70)
433	5B(14)b	0.70	0.32	1.10E-1	0.80	0.36	2.29E-1	2.17E-2	1.38E-2	3.53E-2	2.87E-2	8.74E-2*		ve=0.73vt-vfb			AZ(60-70)
434	5B(14)c	0.70	0.26	1.18E-1	0.80	0.48	2.60E-1	1.40E-2	8.49E-3	2.39E-2	1.94E-2	9.45E-2*		ve=0.73vt-vfb			AZ(60-70)
435	6C(15)a	0.85	0.48	3.00E-1	1.15	0.68	4.81E-1	4.57E-2	2.59E-2	4.50E-2	3.46E-2	2.71E-1*		ve=0.73vt-vfb			AZ(60-70)
436	6C(15)b	0.95	0.43	3.23E-1	1.10	0.63	4.67E-1	4.11E-2	2.32E-2	4.36E-2	3.36E-2	2.46E-1*		ve=0.73vt-vfb			AZ(60-70)
437	7C(16)																AZ(60-70)

Table 8

Cratering Data from Battlefield Environments in Tailored Soils Tests

FORT POLK,LA. (RANGE 37) INORGANIC CLAY

ROW	REF/SR	TEST P/S	A OBS	SHOT ID	X COORD	Y COORD	SOIL DES	USCS	SA,%	SI,%	CL,%	MC,%	DESA,%	TYPE CH	CH WT,kg	E TNT,kg	TN C/M	MO O/A	H/DOB,R
438	29	BETS	1	TS-1	0.00	0.00	ICl	CH	10*	30*	60*	3*	25-65*	TNT	2.27	2.27			1.00
439	29	BETS	1	TS-2	0.00	20.00	ICl	CH	10*	30*	60*	10*	25-65*	TNT	2.27	2.27			1.00
440	29	BETS	1	TS-5	0.00	0.00	ICl	CH	10*	30*	60*	3.0	5*	TNT	2.27	2.27			1.00
441	29	BETS	1	TS-6	0.00	20.00	ICl	CH	10*	30*	60*	3.0	5*	TNT	2.27	2.27			1.00
442	29	BETS	1	TS-17	0.00	20.00	ICl	CH	10*	30*	60*	17.2	28*	TNT	2.27	2.27			1.00
443	29	BETS	1	TS-19	0.00	20.00	ICl	CH	10*	30*	60*	4.8	7*	TNT	2.27	2.27			1.00
444	29	BETS	1	TS-25	0.00	30.00	ICl	CH	10*	30*	60*	22.7	36*	TNT	2.27	2.27			1.00
445	29	BETS	1	TS-29	0.00	20.00	ICl	CH	10*	30*	60*	10*	25-65*	TNT	2.27	2.27			1.00
446	29	BETS	1	TS-28	0.00	30.00	ICl	CH	10*	30*	60*	24.8	35*	TNT	2.27	2.27			1.00
447	29	BETS	1	TS-30	0.00	20.00	ICl	CH	10*	30*	60*	10*	25-65*	TNT	2.27	2.27			1.00

FORT POLK,LA. (RANGE 37) MIXTURE OF INORGANIC SILTS AND CLAYEY SILTS

ROW	REF/SR	TEST P/S	A OBS	SHOT ID	X COORD	Y COORD	SOIL DES	USCS	SA,%	SI,%	CL,%	MC,%	DESA,%	TYPE CH	CH WT,kg	E TNT,kg	TN C/M	MO O/A	H/DOB,R
448	29	BETS	1	TS-3	60.00	0.00	IS(C(S)	ML	5*	60*	35*	9.9	16*	TNT	2.27	2.27			1.00
449	29	BETS	1	TS-4	60.00	20.00	IS(C(S)	ML	5*	60*	35*	10.4	17*	TNT	2.27	2.27			1.00
450	29	BETS	1	TS-7	60.00	0.00	IS(C(S)	ML	5*	60*	35*	15.2	25*	TNT	2.27	2.27			1.00
451	29	BETS	1	TS-8	60.00	20.00	IS(C(S)	ML	5*	60*	35*	7.5	12*	TNT	2.27	2.27			1.00
452	29	BETS	1	TS-16	60.00	20.00	IS(C(S)	ML	5*	60*	35*	24.4	35*	TNT	2.27	2.27			1.00
453	29	BETS	1	TS-26	60.00	20.00	IS(C(S)	ML	5*	60*	35*	26.8	38*	TNT	2.27	2.27			1.00
454	29	BETS	1	TS-31	60.00	30.00	IS(C(S)	ML	5*	60*	35*	9.5	15*	TNT	2.27	2.27			-2.10
455	29	BETS	1	TS-32	60.00	20.00	IS(C(S)	ML	5*	60*	35*	24.0	35*	TNT	2.27	2.27			1.00
456	29	BETS	1	TS-20	60.00	20.00	IS(C(S)	ML	5*	60*	35*	2.8	4*	TNT	4.54	4.54			1.00
457	29	BETS	1	TS-27	60.00	30.00	IS(C(S)	ML	5*	60*	35*	9.9	15*	TNT	2.27	2.27			-1.00

FORT POLK,LA. (RANGE 37) POORLY GRADED SAND

ROW	REF/SR	TEST P/S	A OBS	SHOT ID	X COORD	Y COORD	SOIL_DES	USCS	SA,%	SI,%	CL,%	MC,%	DESA,%	TYPE CH	CH WT,kg	E TNT,kg	TN C/M	MO O/A	H/DOB,R
458	29	BETS	1	TS-21	40.00	0.00	PGSe	SP	90*	5*	5*	3.4	6*	TNT	2.27	2.27			1.00
459	29	BETS	1	TS-22	40.00	20.00	PGSe	SP	90*	5*	5*	4.2	8*	TNT	2.27	2.27			1.00
460	29	BETS	1	TS-23	40.00	0.00	PGSe	SP	90*	5*	5*	3.1	5*	TNT	2.27	2.27			1.00
461	29	BETS	1	TS-24	40.00	20.00	PGSe	SP	90*	5*	5*	3.0	5*	TNT	2.27	2.27			1.00
462	29	BETS	1	TS-35	40.00	30.00	PGSe	SP	90*	5*	5*	10.7	17*	TNT	2.27	2.27			1.00
463	29	BETS	1	TS-36	40.00	20.00	PGSe	SP	90*	5*	5*	10.2	17*	TNT	2.27	2.27			1.00
464	29	BETS	1	TS-37	40.00	30.00	PGSe	SP	90*	5*	5*	9.8	16*	TNT	2.27	2.27			1.00
465	29	BETS	1	TS-38	40.00	20.00	PGSe	SP	90*	5*	5*	8.7	16*	TNT	2.27	2.27			1.00
466	29	BETS	1	TS-46	40.00	20.00	PGSc	SP	90*	5*	5*	3.1	5*	TNT	2.27	2.27			1.00

FORT POLK,LA. (RANGE 37) INORGANIC CLAY/SAND MIXTURE

ROW	REF/SR	TEST P/S	A OBS	SHOT ID	X COORD	Y COORD	SOIL DES	USCS	SA,%	SI,%	CL,%	MC,%	DESA,%	TYPE CH	CH WT,kg	E TNT,kg	TN C/M	MO O/A	H/DOB,R
467	29	BETS	1	TS-13	20.00	0.00	ICl-SaM	CH/SP	30*	20*	50*	10*	25-65*	TNT	2.27	2.27			1.00
468	29	BETS	1	TS-14	20.00	20.00	ICl-SaM	CH/SP	30*	20*	50*	5*	25-65*	TNT	2.27	2.27			1.00

(Continued)

Table 8 (Continued)

FORT POLK,LA. (RANGE 37) INORGANIC CLAY

ROW	SHOT ID	re,m	de,m	Ve,m3	rt,m	dt,m	Vt,m3	Ve'm3/We	Ve/Wn	Vt'm3/kg	Vt/Wn	Ve,m3	We,kg	Ejec Cal	D C Obs	Ks	V/C Obs
438	TS-1	0.80	0.30	3.80E-1				1.87E-1	1.53E-1			4.51E-2	73.52	D=20.04R-4.147			
439	TS-2	0.88	0.26	3.00E-1				1.49E-1	1.21E-1			0.13	205.78	D=88.75R-4.985			
440	TS-5	0.75	0.30	2.70E-1				1.30E-1	1.09E-1			4.33E-2	70.51	D=9.39R-3.172			
441	TS-6	0.74	0.32	2.10E-1				1.35E-1	8.46E-2			3.17E-2	51.73	D=4.70R-2.707			
442	TS-17	0.84	0.48	3.10E-1				1.51E-1	1.26E-2			0.12	207.92	D=19.59R-2.875			
443	TS-19	0.73	0.42	3.80E-1				1.70E-1	1.46E-1			0.15	218.03	D=28.18R-3.168			
444	TS-25	0.80	0.38	2.10E-1				1.05E-1	8.45E-2			0.21	384.21	D=5.70R-2.098			
445	TS-28	0.89	0.55	8.80E-1				3.35E-1	2.74E-1			5.20E-1		ve=0.77ve			
446	TS-29	0.88	0.50	3.80E-1				1.78E-1	1.46E-1			0.35	846.87	D=92.79R-3.815			
447	TS-30	0.80	0.43	2.40E-1				1.19E-1	9.85E-2			1.00E-1		ve=0.77ve			

FORT POLK,LA. (RANGE 37) MIXTURE OF INORGANIC SILTS AND CLAYEY SILTS

ROW	SHOT ID	re,m	de,m	Ve,m3	rt,m	dt,m	Vt,m3	Ve'm3/We	Ve/Wn	Vt'm3/kg	Vt/Wn	Ve,m3	We,kg	Ejec Cal	D C Obs	Ks	V/C Obs
448	TS-3	0.50	0.25	1.00E-1				4.82E-2	4.02E-2			3.39E-2	56.21	D=3.07R-2.478			
449	TS-4	0.48	0.30	1.10E-1				5.34E-2	4.42E-2			8.00E-2		ve=0.56ve			
450	TS-7	0.56	0.30	4.10E-1				7.01E-2	1.65E-1			4.82E-2		ve=0.12ve			
451	TS-8	0.48	0.30	1.10E-1				5.34E-2	4.42E-2			6.16E-2		ve=0.56ve			
452	TS-18	0.89	0.48	5.90E-1				2.83E-1	2.37E-1			8.87E-2	121.88	D=8.58R-2.488			
453	TS-26	0.73	0.49	4.10E-1				2.01E-1	1.84E-1			4.92E-2		ve=0.12ve			
454	TS-31	0.90	0.60	6.40E-1				3.11E-1	2.57E-1			3.58E-1		ve=0.56ve			
455	TS-32	0.88	0.80	7.20E-1				3.58E-1	2.90E-1			8.84E-2		ve=0.12ve			
456	TS-20	1.00	0.50	7.80E-1				2.11E-1	1.47E-1			0.60	1088.83	D=398.18R-4.329			
457	TS-27	0.98	0.45	6.70E-1				3.33E-1	2.69E-1			3.75E-1		ve=0.56ve			

FORT POLK,LA. (RANGE 37) POORLY GRADED SAND

ROW	SHOT ID	re,m	de,m	Ve,m3	rt,m	dt,m	Vt,m3	Ve'm3/We	Ve/Wn	Vt'm3/kg	Vt/Wn	Ve,m3	We,kg	Ejec Cal	D C Obs	Ks	V/C Obs
458	TS-21	0.88	0.32	2.30E-1				1.13E-1	9.25E-2			1.15E-1		ve=0.50ve			
459	TS-22	0.71	0.29	2.30E-1				1.12E-1	9.25E-2			1.15E-1		ve=0.50ve			
460	TS-23	0.72	0.33	2.70E-1				1.32E-1	1.08E-1			0.13	208.39	D=32.11R-3.720			
461	TS-24	1.13	0.25	5.00E-1				2.45E-1	2.01E-1			2.50E-1		ve=0.50ve			
462	TS-35	1.29	0.20	1.30E-1				2.59E-1	5.23E-2			4.29E-2		ve=0.33ve			
463	TS-36	0.78	0.25	2.30E-1				1.11E-1	9.26E-2			7.59E-2		ve=0.33ve			
464	TS-37	0.72	0.28	2.30E-1				1.12E-1	9.26E-2			7.49E-2	124.98	D=12.84R-2.855			
465	TS-38	0.70	0.25	1.90E-1				9.41E-2	7.84E-2			9.50E-2		ve=0.50ve			
466	TS-46	1.00	0.22	3.50E-1				1.69E-1	1.41E-1			0.18	305.82	D=117.78R-4.42			

FORT POLK,LA. (RANGE 37) INORGANIC CLAY/SAND MIXTURE

ROW	SHOT ID	re,m	de,m	Ve,m3	rt,m	dt,m	Vt,m3	Ve'm3/We	Ve/Wn	Vt'm3/kg	Vt/Wn	Ve,m3	We,kg	Ejec Cal	D C Obs	Ks	V/C Obs
467	TS-13	0.86	0.28	1.90E-1				9.11E-2	7.84E-2			0.32	528.28	D=71.40R-4.187			
468	TS-14	0.72	0.30	2.50E-1				1.19E-1	1.01E-1			5.02E-2	83.36	D=12.48R-3.576			

(Continued)

Table 8 (Concluded)

FORT POLK,LA. (RANGE 37) SANDY SILT

ROW	REF/BR	TEST P/B	A OBS	SHOT ID	X COORD	Y COORD	SOIL DES	USCS	SA,%	SI,%	CL,%	MC,%	DESA,%	TYPE CH	CH WT,kg	E TNT,kg	TM C/M	MO D/A	H/DOB,R
469	29	BETS	1	TS-11	60.00	0.00	SaSi	ML/SP	40*	50*	10*	17.4	30*	TNT	2.27	2.27			1.00
470	29	BETS	1	TS-12	60.00	20.00	SaSi	ML/SP	40*	50*	10*	16.2	26*	TNT	2.27	2.27			1.00
471	29	BETS	1	TS-15	60.00	0.00	SaSi	ML/SP	40*	50*	10*	8.8	10*	TNT	2.27	2.27			1.00
472	29	BETS	1	TS-18	60.00	20.00	SaSi	ML/SP	40*	50*	10*	6.4	10*	TNT	2.27	2.27			1.00
473	29	BETS	1	TS-42	60.00	20.00	SaSi	ML/SP	40*	50*	10*	7.9	12*	TNT	2.27	2.27			1.00
474	29	BETS	1	TS-43	60.00	20.00	SaSi	ML/SP	40*	50*	10*	5.6	8*	TNT	2.27	2.27			1.00
475	29	BETS	1	TS-44	60.00	20.00	SaSi	ML/SP	40*	50*	10*	7.8	12*	TNT	2.27	2.27			1.00

FORT POLK,LA. (RANGE 37) KAOLIN

ROW	REF/BR	TEST P/S	A OBS	SHOT ID	X COORD	Y COORD	SOIL_DES	USCS	SA,%	SI,%	CL,%	MC,%	DESA,%	TYPE CH	CH WT,kg	E TNT,kg	TM C/M	MO D/A	H/DOB,R
476	29	BETS	1	TS-33	20.00	0.00	Kaolin	CH	10*	20*	70*	0.5	1*	TNT	2.27	2.27			-2.10
477	29	BETS	1	TS-34	20.00	20.00	Kaolin	CH	10*	20*	70*	10-30A20	25-65*	TNT	2.27	2.27			-2.10
478	29	BETS	1	TS-39	20.00	20.00	Kaolin	CH	10*	20*	70*	10-30A20	25-65*	TNT	2.27	2.27			1.00

FORT POLK,LA. (RANGE 37) SANDY SILT

ROW	SHOT ID	ra,m	da,m	Va,m3	rt,m	dt,m	Vt,m3	Va'm3/We	Va/Wn	Vt'm3/kg	Vt/Wn	Ve,m3	We,kg	Ejec Cal	D C Obs	Ke	V/C Dee
469	TS-11	0.79	0.40	3.90E-1				1.92E-1	1.57E-1			5.47E-2	101.65	D=9.17R-2.858			
470	TS-12	0.65	0.48	3.20E-1				1.57E-1	1.29E-1			1.73E-1		ve=0.54va			
471	TS-15	0.43	0.28	9.00E-2				3.88E-2	3.22E-2			6.09E-2	108.40	D=8.07R-2.589			
472	TS-18	0.58	0.33	1.70E-1				8.53E-2	6.84E-2			4.12E-2	74.14	D=6.74R-2.719			
473	TS-42	0.48	0.26	1.00E-1				4.86E-2	4.02E-2			5.40E-2		ve=0.54va			
474	TS-43	0.88	0.38	2.50E-1				1.20E-1	1.01E-2			0.27	486.24	D=60.30R-2.946			
475	TS-44	0.89	0.63	7.80E-1				3.84E-1	3.14E-1			0.36	612.30	D=92.35R-3.074			

FORT POLK,LA. (RANGE 37) KAOLIN

ROW	SHOT ID	ra,m	da,m	Va,m3	rt,m	dt,m	Vt,m3	Va'm3/We	Va/Wn	Vt'm3/kg	Vt/Wn	Ve,m3	We,kg	Ejec Cal	D C Obs	Ke	V/C Dee
476	TS-33	0.72	0.30	2.50E-1				1.19E-1	1.01E-2			2.50E-1		ve=1.0va			
477	TS-34	0.65	0.33	3.70E-1				1.04E-1	1.49E-1			3.70E-1		ve=1.0va			
478	TS-39	0.79	0.36	3.40E-1				1.09E-1	1.37E-1			3.40E-1		ve=1.0va			

(Sheet 3 of 3)

Table 9

Cratering Data from Live-Fired Munitions

ROW	REF/SR	TEST P/S	A OBS	SHOT ID	X COORD	Y COORD	SOIL DES	USCS	SA.%	SI.%	CL.%	MC.%	DESA.%	TYPE CH	CH WT.kg	E TNT.kg	TN C/M	MD D/A	H/DOB.R
FORT BENNING,GA. (COOLIDGE MORTAR RANGE) MOIST SILTY SAND																			
479	15	PST	1	L-1			MSiSand	SM	60*	30*	10*	5*	7*	COMPB	0.86	1.04	81/M374		4.00
480	15	PST	1	L-2			MSiSand	SM	60*	30*	10*	5*	7*	COMPB	0.86	1.04	81/M374		4.00
481	15	PST	1	L-3			MSiSand	SM	60*	30*	10*	5*	7*	COMPB	0.86	1.04	81/M374		4.00
482	15	PST	1	L-4			MSiSand	SM	60*	30*	10*	5*	7*	COMPB	0.86	1.04	81/M374		4.00
483	15	PST	1	L-5			MSiSand	SM	60*	30*	10*	5*	7*	TNT	3.54	3.54	4.2/M329		3.30
484	15	PST	1	L-6			MSiSand	SM	60*	30*	10*	5*	7*	TNT	3.54	3.54	4.2/M329		3.30
FORT BENNING,GA. (SPAFFORD ARTILLERY RANGE) MOIST SILTY SAND																			
ROW	REF/SR	TEST P/S	A OBS	SHOT ID	X COORD	Y COORD	SOIL DES	USCS	SA.%	SI.%	CL.%	MC.%	DESA.%	TYPE CH	CH WT.kg	E TNT.kg	TN C/M	MD D/A	H/DOB.R
485	15	PST	1	L-7			MSiSand	SM	60*	30*	10*	5*	7*	COMPB	2.30	2.53	105/M1		0.80
486	15	PST	1	L-8			MSiSand	SM	60*	30*	10*	5*	7*	COMPB	2.30	2.53	105/M1		0.80
487	15	PST	1	L-9			MSiSand	SM	60*	30*	10*	5*	7*	COMPB	2.30	2.53	105/M1		0.80
488	15	PST	1	L-10			MSiSand	SM	60*	30*	10*	5*	7*	COMPB	2.30	2.53	105/M1		0.80
489	15	PST	1	L-11			MSiSand	SM	60*	30*	10*	5*	7*	COMPB	2.30	2.53	105/M1		0.80
490	15	PST	1	L-12			MSiSand	SM	60*	30*	10*	5*	7*	COMPB	2.30	2.53	105/M1		0.80
WHITE SANDS MISSILE RANGE,NM. (OROGRANDE) DRY SILTY SAND																			
ROW	REF/SR	TEST P/S	A OBS	SHOT ID	X COORD	Y COORD	SOIL DES	USCS	SA.%	SI.%	CL.%	MC.%	DESA.%	TYPE CH	CH WT.kg	E TNT.kg	TN C/M	MD D/A	H/DOB.R
491	21	DIRT I	50	AVG			SiSa	SM	60*	35*	5*	3-13	20*	TNT	6.62	6.62	155/M107		1.00
WHITE SANDS MISSILE RANGE,NM. (QUEEN 15) SILTY SANDY CLAY																			
ROW	REF/SR	TEST P/S	A OBS	SHOT ID	X COORD	Y COORD	SOIL DES	USCS	SA.%	SI.%	CL.%	MC.%	DESA.%	TYPE CH	CH WT.kg	E TNT.kg	TN C/M	MD D/A	H/DOB.R
492	20	DIRT II	1	T1			MSaSiCl	CL/ML	15*	35*	50*	10-15*	30*	TNT	6.62	6.62	155/M107		1.00
493	20	DIRT II	1	T2			MSaSiCl	CL/ML	15*	35*	50*	10-15*	30*	TNT	6.62	6.62	155/M107		1.00
494	20	DIRT II	1	T4			MSaSiCl	CL/ML	15*	35*	50*	10-15*	30*	TNT	6.62	6.62	155/M107		1.00
495	20	DIRT II	1	T5			MSaSiCl	CL/ML	15*	35*	50*	10-15*	30*	TNT	6.62	6.62	155/M107		1.00
496	20	DIRT II	1	T6			MSaSiCl	CL/ML	15*	35*	50*	10-15*	30*	TNT	6.62	6.62	155/M107		1.00
497	20	DIRT II	1	T7			MSaSiCl	CL/ML	15*	35*	50*	10-15*	30*	TNT	6.62	6.62	155/M107		1.00
498	20	DIRT II	1	T8			MSaSiCl	CL/ML	15*	35*	50*	10-15*	30*	TNT	6.62	6.62	155/M107		1.00
499	20	DIRT II	1	T16			MSaSiCl	CL/ML	15*	35*	50*	10-15*	30*	TNT	6.62	6.62	155/M107		1.00
500	20	DIRT II	1	T26			MSaSiCl	CL/ML	15*	35*	50*	10-15*	30*	TNT	6.62	6.62	155/M107		1.00
501	20	DIRT II	1	T28			MSaSiCl	CL/ML	15*	35*	50*	10-15*	30*	TNT	6.62	6.62	155/M107		1.00
502	21	DIRT II	7	AVG			MSaSiCl	CL/ML	15*	35*	50*	10-15*	30*	TNT	6.62	6.62	155/M107		1.00
503	31	DIRT II	7	AVG			MSaSiCl	CL/ML	15*	35*	50*	10-15*	30*	TNT	6.62	6.62	155/M107		1.00
504	20	DIRT II	1	T9			MSaSiCl	CL/ML	15*	35*	50*	10-15*	30*	COMPB	2.30	2.53	105/M1		0.80
505	20	DIRT II	1	T10			MSaSiCl	CL/ML	15*	35*	50*	10-15*	30*	COMPB	2.30	2.53	105/M1		0.80
506	20	DIRT II	1	T11			MSaSiCl	CL/ML	15*	35*	50*	10-15*	30*	COMPB	2.30	2.53	105/M1		0.80
507	20	DIRT II	1	T12			MSaSiCl	CL/ML	15*	35*	50*	10-15*	30*	COMPB	2.30	2.53	105/M1		0.80
508	20	DIRT II	1	T18			MSaSiCl	CL/ML	15*	35*	50*	10-15*	30*	COMPB	2.30	2.53	105/M1		0.80
509	20	DIRT II	1	T19			MSaSiCl	CL/ML	15*	35*	50*	10-15*	30*	COMPB	2.30	2.53	105/M1		0.80
510	20	DIRT II	1	T20			MSaSiCl	CL/ML	15*	35*	50*	10-15*	30*	COMPB	2.30	2.53	105/M1		0.80
511	20	DIRT II	1	T21			MSaSiCl	CL/ML	15*	35*	50*	10-15*	30*	COMPB	2.30	2.53	105/M1		0.80
512	20	DIRT II	1	T22			MSaSiCl	CL/ML	15*	35*	50*	10-15*	30*	COMPB	2.30	2.53	105/M1		0.80
513	20	DIRT II	1	T27			MSaSiCl	CL/ML	15*	35*	50*	10-15*	30*	COMPB	2.30	2.53	105/M1		0.80
514	20	DIRT II	1	T29			MSaSiCl	CL/ML	15*	35*	50*	10-15*	30*	COMPB	2.30	2.53	105/M1		0.80
515	21	DIRT II	11	AVG			MSaSiCl	CL/ML	15*	35*	50*	10-15*	30*	COMPB	2.30	2.53	105/M1		0.80
516	20	DIRT II	11	AVG			MSaSiCl	CL/ML	15*	35*	50*	10-15*	30*	COMPB	2.30	2.53	105/M1		0.80

(Continued)

Table 9 (Concluded)

FORT BENNING,GA. (COOLIDGE MORTAR RANGE) MOIST SILTY SAND

ROW	SHOT ID	ra,m	da,m	Va,m3	rt,m	dt,m	Vt,m3	Va'm3/Wa	Va/Wn	Vt'm3/kg	Vt/Wn	Ve,m3	We,kg	Ejec Cal	D C Obs	Ke	V/C Des
479	L-1	0.58	0.08	3.08E-2*				3.18E-2*	2.95E-2*			1.60E-2		ve=0.52va		0.32/-	
480	L-2	0.49	0.12	2.90E-2*				2.80E-2*	2.75E-2*			1.51E-2		ve=0.52va		0.32/-	
481	L-3	0.82	0.17	6.58E-2*				6.34E-2*	6.28E-2*			3.41E-2		ve=0.52va		0.32/-	
482	L-4	1.01	0.17	1.74E-1*				1.68E-1*	1.67E-1*			9.05E-2		ve=0.52va		0.32/-	
483	L-5	0.88	0.14	6.70E-2*				2.23E-2*	1.84E-2*			3.49E-2		ve=0.52va		0.28/-	
484	L-6	0.52	0.24	6.52E-2*				2.17E-2*	1.80E-2*			3.39E-2		ve=0.52va		0.28/-	

FORT BENNING,GA. (SPAFFORD ARTILLERY RANGE) MOIST SILTY SAND

ROW	SHOT ID	ra,m	da,m	Va,m3	rt,m	dt,m	Vt,m3	Va'm3/Wa	Va/Wn	Vt'm3/kg	Vt/Wn	Ve,m3	We,kg	Ejec Cal	D C Obs	Ke	V/C Des
485	L-7	1.20	0.44	6.37E-1*				2.83E-1*	2.29E-1*			3.31E-1		ve=0.52va		0.32/-	
486	L-8	1.22	0.44	6.58E-1*				2.82E-1*	2.34E-1*			3.42E-1		ve=0.52va		0.32/-	
487	L-9	0.93	0.38	3.30E-1*				1.47E-1*	1.18E-1*			1.72E-1		ve=0.52va		0.32/-	
488	L-10	1.16	0.30	4.06E-1*				1.81E-1*	1.44E-1*			2.11E-1		ve=0.52va		0.32/-	
489	L-11	0.78	0.40	2.51E-1*				1.11E-1*	8.95E-2*			1.31E-1		ve=0.52va		0.32/-	
490	L-12	0.87	0.38	1.71E-1*				7.83E-2*	6.10E-2*			8.89E-2		ve=0.52va		0.32/-	

WHITE SANDS MISSILE RANGE,NM. (OROGRANDE) DRY SILTY SAND

ROW	SHOT ID	ra,m	da,m	Va,m3	rt,m	dt,m	Vt,m3	Va'm3/Wa	Va/Wn	Vt'm3/kg	Vt/Wn	Ve,m3	We,kg	Ejec Cal	D C Obs	Ke	V/C Des
491	AVG	0.72	0.37	2.71E-1*				5.23E-2*	3.32E-2*			1.41E-1		ve=0.52va		0.46/-	

WHITE SANDS MISSILE RANGE,NM. (QUEEN 15) SILTY SANDY CLAY

ROW	SHOT ID	ra,m	da,m	Va,m3	rt,m	dt,m	Vt,m3	Va'm3/Wa	Va/Wn	Vt'm3/kg	Vt/Wn	Ve,m3	We,kg	Ejec Cal	D C Obs	Ke	V/C Des
492	T1	1.12	0.80	1.16*				2.24E-1*	1.42E-1*			6.03E-1		ve=0.52va		0.49/-	
493	T2	0.95	0.70	9.73E-1*				1.88E-1*	1.19E-1*			5.06E-1		ve=0.52va		0.49/-	
494	T4	0.82	0.59	6.00E-1*				1.16E-1*	7.33E-1*			3.12E-1		ve=0.52va		0.49/-	
495	T5	0.68	0.50	3.56E-1*				6.88E-2*	4.36E-2*			1.85E-1		ve=0.52va		0.49/-	
496	T6	0.72	0.55	4.39E-1*				8.48E-2*	5.38E-2*			2.28E-1		ve=0.52va		0.49/-	
497	T7	0.72	0.45	3.59E-1*				6.93E-2*	4.40E-2*			1.87E-1		ve=0.52va		0.49/-	
498	T8	0.80	0.50	4.93E-1*				9.52E-2*	6.04E-2*			2.56E-1		ve=0.52va		0.49/-	
499	T15	1.15	0.80	1.22*				2.36E-1*	1.49E-1*			6.34E-1		ve=0.52va		0.49/-	
500	T26	0.80	0.50	4.93E-1*				9.52E-2*	6.04E-2*			2.56E-1		ve=0.52va		0.49/-	
501	T28	0.85	0.50	5.56E-1*				1.07E-1*	6.81E-2*			2.89E-1		ve=0.52va		0.49/-	
502	AVG	0.86	0.55	6.26E-1*				1.21E-1*	7.67E-2*					ve=0.52va		0.49/-	
503	AVG			6.30E-1				1.22E-1*	7.71E-2*					ve=0.52va		0.49/-	
504	T9	0.62	0.30	1.88E-1*				8.38E-2*	6.71E-2*			9.78E-2		ve=0.52va		0.52/-	
505	T10	0.48	0.30	1.13E-1*				5.04E-2*	4.04E-2*			5.88E-2		ve=0.52va		0.52/-	
506	T11	0.45	0.25	8.27E-2*				3.69E-2*	2.95E-2*			4.30E-2		ve=0.52va		0.52/-	
507	T12	0.49	0.25	9.41E-2*				4.19E-2*	3.35E-2*			4.89E-2		ve=0.52va		0.52/-	
508	T18	0.80	0.65	3.82E-1*				1.70E-2*	1.36E-1*			1.99E-1		ve=0.52va		0.52/-	
509	T19	0.58	0.28	1.54E-1*				6.87E-2*	5.50E-2*			8.01E-2		ve=0.52va		0.52/-	
510	T20	0.55	0.30	1.48E-1*				6.60E-2*	5.29E-2*			7.70E-2		ve=0.52va		0.52/-	
511	T21	0.52	0.35	1.55E-1*				6.91E-2*	5.53E-2*			8.06E-2		ve=0.52va		0.52/-	
512	T22	0.42	0.35	1.01E-1*				4.50E-2*	3.61E-2*			5.25E-2		ve=0.52va			
513	T27	0.50	0.35	1.20E-1*				5.35E-2*	4.28E-2*			2.64E-2		ve=0.52va		0.52/-	
514	T28	0.58	0.25	1.37E-1*				6.12E-2*	4.89E-2*			7.12E-2		ve=0.52va		0.52/-	
515	AVG	0.52	0.30	1.33E-1*				5.93E-2*	4.74E-2*					ve=0.52va		0.52/-	
516	AVG			1.33E-1				5.93E-2	4.74E-2					ve=0.52va		0.52/-	

Table 10

Projectile Crater-Shape Factors

Plot Designation (Figure 4)	Event(s)	Location	Projectile	HOB/DOB R_c	α deg	$\bar{r}_a$ m	$\bar{d}_a$ m	$\bar{r}_a/\bar{d}_a$	$\bar{V}_a$ m^3	K_s	Remarks
A	PBT-L-1-4	Ft. Benning	81-mm	+4.0	~80 (live)	0.67	0.14	4.89	0.061	0.32	
B	PBT-L-5,-6	Ft. Benning	4.2-in.	+3.3	~62 (live)	0.61	0.20	3.08	0.060	0.26	
C	PBT-L-7-12	Ft. Benning	105-mm	+0.8	~16 (live)	0.99	0.40	2.50	0.39	0.32	
D	DIRT-II-T*	WSMR	155-mm	+1.0	? (live)	0.86	0.55	1.56	0.63	0.49	
E	DIRT-II-T*	WSMR	105-mm	+0.8	? (live)	0.52	0.30	1.73	0.14	0.52	
F	PBT-S-2	Ft. Benning	81-mm	+2.1	80	0.56	0.23	2.43	0.12	0.53	
G	PBT-S-7	Ft. Benning	4.2-in.	+2.4	62	0.70	0.21	3.33	0.070	0.21	
H	PBT-S-10,-11	Ft. Benning	105-mm	-0.0	16	0.87	0.43	2.02	0.35	0.35	
I	MBCE-II-A1-3	Ft. Polk	155-mm	+1.0	20	1.18	0.53	2.23	1.10	0.47	
J	MBCE-II-A4-6	Ft. Polk	155-mm	-1.0	20	1.15	0.68	1.69	2.10	0.74	
K	MBCE-II-B1-3	Ft. Polk	105-mm	+0.8	20	0.66	0.29	2.27	0.31	0.78	
L	MBCE-II-B4-7	Ft. Polk	105-mm	-0.9	20	1.28	0.62	2.06	1.00	0.31	
M	MBCE-II-D1**	Ft. Polk	122-mm	+1.2	20	0.92	0.38	2.38	0.51	0.50	USSR Projectile
N	MBCE-II-D4**	Ft. Polk	122-mm	-1.2	20	1.12	0.60	1.86	1.25	0.53	USSR Projectile
O	MBCE-II-E1-4	Ft. Polk	152-mm	+1.1	20	1.02	0.38	2.70	0.76	0.60	USSR Projectile
P	MBCE-II-E5-8	Ft. Polk	152-mm	-1.1	20	1.25	0.68	1.84	3.35	1.00	USSR Projectile
Q	BOT-6-**	TTC Range 6	105-mm	+1.3	30	0.86	0.21	4.10	0.21	0.43	
R	BOT-61-63	TTC Mindi Farm	105-mm	+1.3	30	0.89	0.29	3.07	0.23	0.32	
S	BOT-9-**	TTC Range 6	155-mm	+1.5	30	1.14	0.26	4.38	0.51	0.48	
T	BOT-64-66	TTC Mindi Farm	155-mm	+1.5	30	0.98	0.42	2.33	0.57	0.45	

* See Table 9 for listing of individual events.
** See Table 5 for listing of individual events.

Table 11

Comparison of Munitions-Data Curve Fits

Source of Data	Figure	Type Curve, Values, and Index of Determination I*											
		$Y = A + BX$			$Y = Ae^{BX}$			$Y = AX^B$			$Y = A + B/X$		
		A	B	I	A	B	I	A	B	I	A	B	I
All munitions	20b	4.44E-2	1.43E-1	1.83E-1	1.25E-1	2.70E-1	1.16E-1	1.04E-1	1.02	1.05E-1	1.07	-1.31	1.33E-1
Live fire	21a	-3.63E-2	9.89E-2	4.73E-1	6.48E-2	3.30E-1	4.51E-1	5.56E-2	1.20	4.35E-1	6.01E-1	-7.09E-1	3.03E-1
Live plus selected static	21b	-7.18E-3	9.86E-2	4.46E-1	8.56E-2	2.84E-1	4.34E-1	7.13E-2	1.07	3.81E-1	6.97E-1	-9.00E-1	2.81E-1

* A "goodness of fit" indicator. $I = 1 - \frac{(\text{Standard error of estimate})^2}{\text{Variance}}$; as fit improves, $I \longrightarrow 1$.

Table 12

Cratering Results for 105- and 155-mm HE Projectiles in Live or Simulated Live Fire

Type of Fire	Projectile Caliber	Test Site	Estimated Soil Degree of Saturation percent	Projectile Angle from Horizontal (Static) deg	Height of Burst (Static) R_c	Average Apparent-Crater Volume m^3	Statistics: No. of Observations n	Statistics: Standard Deviation σ_{n-1}	Statistics: 95-percent Confidence Interval* σ_{n-1}	Statistics: 95-percent Confidence Interval* $t_{0.975}$
Live	105	Ft. Benning	7	-	-	4.10E-1	6	2.01E-1	±3.94E-1	+5.17E-1
Live	105	WSMR**	30	-	-	1.53F-1	11	8.85E-2	±1.73E-1	±1.97E-1
Live	155	WSMR	20	-	-	2.71E-1	50	Not Available		
Live	155	WSMR	30	-	-	6.61E-1	10	3.27E-1	±6.41E-1	±7.39E-1
Static	105	WSMR	30	20	0.83	3.18E-1	3	1.73E-1	±3.40E-1	±7.45E-1
Static	105	WSMR	30	10	0.42	2.28E-1	3	9.49E-2	±1.86E-1	±4.08E-1
Static	105	WSMR	30	10-20	0.42-0.83	2.73E-1	6	1.34E-1	±2.63E-1	±3.45E-1
Static	105	Ft. Polk	42 (avg)	20	0.83	3.15E-1	3	1.01E-1	±1.98E-1	±4.34E-1
Static	105	Ft. Benning	7	16	0.80	1.05E-1	2	-	-	-
Static	105	TTC Range 6	68 (avg)	30	1.30	2.09E-1	14	6.84E-2	±1.34E-1	±1.48E-1
Static	105	TTC Mindi Farm	85	30	1.30	2.33E-1	3	6.03E-2	±1.18E-1	±2.59E-1
Static	155	WSMR	30	20-30	1.04-1.52	6.65E-1	5	7.10E-2	±1.39E-1	±1.98E-1
Static	155	WSMR	30	11.5-15	0.61-0.79	1.05	4	2.55E-1	±5.00E-1	±8.10E-1
Static	155	Ft. Polk	42 (avg)	20	1.04	1.11	3	5.51E-2	±1.08E-1	±2.37E-1
Static	155	TTC Range 6	67 (avg)	30	1.50	5.09F-1	15	1.68E-1	±3.29E-1	±3.60E-1
Static	155	TTC Mindi Farm	85	30	1.50	6.00E-1	3	1.68E-1	±3.29E-1	±7.23E-1
Live & static	105	-----------All above 105 observations----------				2.71E-1	45†	1.33E-1	±2.61E-1	±2.69E-1
Live & static	155	-----------All above 155 observations----------				4.49E-1	90† ††	2.86E-1	±5.60E-1	±5.77E-1

* Interval calculations based upon σ_{n-1} for 95-percent area under normal curve or for Student's t-distribution for 5-percent tail.

** Queen 15 area.

† Statistics based upon σ (not σ_{n-1}).

†† 50-shot series treated as single data point for purpose of calculating confidence intervals.

Table 13

Crater/Ejecta Parameters and Statistics for Artillery Projectiles

Shot identification	Test Site	Projectile Caliber mm	$(V_c + V_{fl})$ 105 m^3	$(V_c + V_{fl})$ 155 m^3	Measured V_e* 105 m^3	Measured V_e* 155 m^3	V_e/V_a 105 m^3	V_e/V_a 155 m^3	Combined Sample Statistics** n	$\bar{x}$	σ	σ_{n-1}	95-% Confidence Interval σ	σ_{n-1}	$t_{0.975}$	Remarks
BOT-6†	TTC-6††	105	--	--	0.18	--	0.73	--	--	--	--	--	--	--	--	--
BOT-7	TTC-6	105	--	--	0.056	--	0.33	--	--	--	--	--	--	--	--	--
BOT-8	TTC-6	105	0.16	--	0.049	--	0.27	--	--	--	--	--	--	--	--	--
BOT-9	TTC-6	155	--	--	--	0.16	--	0.24	--	--	--	--	--	--	--	--
BOT-10	TTC-6	155	--	--	--	0.46	--	1.36	--	--	--	--	--	--	--	--
BOT-11	TTC-6	105	0.28	--	0.10	--	0.76	--	--	--	--	--	--	--	--	--
BOT-12	TTC-6	105	--	--	0.055	--	0.28	--	--	--	--	--	--	--	--	--
BOT-13	TTC-6	105	0.03	--	0.16	--	0.18	--	--	--	--	--	--	--	--	--
BOT-14	TTC-6	155	--	--	--	0.34	--	0.68	--	--	--	--	--	--	--	--
BOT-15	TTC-6	155	--	-0.09(?)	--	0.47	--	1.47	--	--	--	--	--	--	--	Invalid volumetric balance
BOT-16	TTC-6	155	--	--	--	0.21	--	0.29	--	--	--	--	--	--	--	--
BOT-19	TTC-6	155	--	0.31	--	0.15	--	0.35	--	--	--	--	--	--	--	--
BOT-33	TTC-6	105	--	--	0.087	--	0.46	--	--	--	--	--	--	--	--	--
BOT-34	TTC-6	105	--	--	0.039	--	0.24	--	--	--	--	--	--	--	--	--
BOT-35	TTC-6	105	0.23	--	0.082	--	0.27	--	--	--	--	--	--	--	--	--
BOT-36	TTC-6	155	--	--	--	0.049	--	0.12	--	--	--	--	--	--	--	--
BOT-37	TTC-6	155	--	--	--	0.59	--	0.91	--	--	--	--	--	--	--	--
BOT-38	TTC-6	155	--	0.54	--	0.14	--	0.22	--	--	--	--	--	--	--	--
BOT-39	TTC-6	105	--	--	0.046	--	0.26	--	--	--	--	--	--	--	--	--
BOT-40	TTC-6	105	--	--	0.10	--	1.01	--	--	--	--	--	--	--	--	--
BOT-41	TTC-6	105	--	--	0.27	--	1.56	--	--	--	--	--	--	--	--	--
BOT-46	TTC-6	155	--	--	--	0.42	--	0.67	--	--	--	--	--	--	--	--
BOT-48	TTC-6	155	--	--	--	0.12	--	0.34	--	--	--	--	--	--	--	--
BOT-49	TTC-6	155	--	-0.060(?)	--	0.61	--	1.13	--	--	--	--	--	--	--	Invalid volumetric balance
Summary																
	TTC-6		$n = 4$	$n = 2$	$n = 12$	$n = 10$	$n = 12$	$n = 10$	22	0.52	--	0.39	--	±0.76	±0.81	--
			$\bar{x} = 0.18$	$\bar{x} = 0.42$	$\bar{x} = 0.10$	$\bar{x} = 0.26$	$\bar{x} = 0.53$	$\bar{x} = 0.52$								
			$\sigma_{n-1} = 0.11$		$\sigma_{n-1} = 0.069$	$\sigma_{n-1} = 0.18$	$\sigma_{n-1} = 0.42$	$\sigma_{n-1} = 0.39$								
BOT-61	TTC-MF	105	--	--	0.13	--	0.74	--	--	--	--	--	--	--	--	--
BOT-62	TTC-MF	105	--	--	0.045	--	0.19	--	--	--	--	--	--	--	--	--
BOT-63	TTC-MF	105	0.25	--	0.053	--	0.18	--	--	--	--	--	--	--	--	--
BOT-64	TTC-MF	155	--	--	--	0.31	--	0.44	--	--	--	--	--	--	--	--
BOT-655	TTC-MF	155	--	--	--	0.33	--	0.59	--	--	--	--	--	--	--	--
BOT-66	TTC-MF	155	--	0.04	--	0.47	--	1.05	--	--	--	--	--	--	--	--
Summary																
	TTC-MF		$n = 1$	$n = 1$	$n = 3$	$n = 3$	$n = 3$	$n = 3$	6	0.53	--	0.34	--	±0.67	±0.87	--
					$\bar{x} = 0.076$	$\bar{x} = 0.37$	$\bar{x} = 0.37$	$\bar{x} = 0.69$	--	--	--	--	--	--	--	--
					$\sigma_{n-1} = 0.047$	$\sigma_{n-1} = 0.087$	$\sigma_{n-1} = 0.32$	$_{n-1} = 0.32$	--	--	--	--	--	--	--	--
T-27	WSMR-Q-15‡	105					0.22‡‡									
Summary of all events, three test sites									29	0.52	0.37	0.37	±0.72	±0.73	±0.76	--

* In situ.
** n = number of valid observations; $\bar{x}$ = mean; = standard deviation of the mean; t = Student's t. Note that the small-sample $_{n-1}$ is used except where n + 30 .
† Battlefield Obscuration in the Tropics--(Range number or name).
†† Tropic Test Center--(Range No. or name). MF = Mindi Farm.
‡ White Sands Missile Range, Queen 15.
‡‡ Only live-fire data available; obtained by assuming $(V_c + V_{fl})$, based upon TTC data.
Note: All events are static fire except T-27.

Table 14

Bare-Charge Ejecta/Apparent Crater Volume Relations

Soil Description	Site/Test	HOB R_c	V_e/V_a	n	Statistics* 95-percent confidence σ_{n-1}	$t_{0.975}$	Remarks
Sand, dry	WES	0	0.81	1	-	-	
Loess (CL, OL), moist	Compendium	+1.0 to +1.2	$\bar{x}$ = 0.79**	7	±0.29	±0.37	
		0	$\bar{x}$ = 0.78	10	±0.061	±0.070	
		-1.0 to -1.2	$\bar{x}$ = 0.76	6	±0.028	±0.036	
Ottowa Sand (SP), dry	Univ. of Dayton Research Institute	+1.5 to +2.0	0.8	-	-	-	Inferred from scaled ejecta-depth measurements in small-scale experiments
		+1.0	1.8	-	-	-	
		-1.0	0.5	-	-	-	
Plasticene clay, dry	Physics International	+1.0	0.37	1	-	-	Battlefield Environments in Tailored Soils-80 B test series
Plastic clay (CH), dry	Ft. Polk, Range 37	+1.0	$\bar{x}$ = 0.25	5	±0.31	±0.44	
Plastic clay, moist	Ft. Polk, Range 37	+1.0	$\bar{x}$ = 0.77	3	±0.59	±1.46	
Silt (ML), dry	Ft. Polk, Range 37	+1.0	$\bar{x}$ = 0.56	2	-	-	
Silt (ML), moist	Ft. Polk, Range 37	+1.0	0.12	1	-	-	
Sand (SP), dry	Ft. Polk, Range 37	+1.0	$\bar{x}$ = 0.50	2	-	-	
Sand (SP), moist	Ft. Polk, Range 37	+1.0	0.33	1	-	-	
Silt/sand (ML-SP) dry-to-moist	Ft. Polk, Range 37	+1.0	$\bar{x}$ = 0.54	5	±0.76	±1.08	
Clay/sand (CH-SP), dry	Ft. Polk, Range 37	+1.0	$\bar{x}$ = 0.96	2	-	-	
sandy clay-sandy silt (CL)	Ft. Carson	+1.0 to -1.0	$\bar{x}$ = 0.72	2	-	-	Dust Obscuration Test II Series
Lean clay (CL), dry		-1.4	0.90	1	-	-	Underground Explosion Test Program (UETP)
Lean clay (CL), dry		-1.9	1.07	1	-	-	Project MOLE
Sand (SW), wet		+3.75	0.73	1	-	-	UETP
Sand (SW), wet		+1.0	1.4	1	-	-	MOLE
Sand (SW), wet		0	$\bar{x}$ = 0.87	2	-	-	MOLE, UETP
Sand (SW), wet		-1.0	0.81	1	-	-	MOLE
Sand (SW), wet		-1.4	0.79	1	-	-	UETP

* Statistical notation: n = number of observations in sample; σ_{n-1} = standard deviation of sample; $t_{0.975}$ = Student's t-distribution, n - 1 degrees of freedom.

** $\bar{x}$ = sample mean (n > 1).